

DESIGNING GREEN CATALYSTS FOR ADVANCING SUSTAINABLE APPROACHES IN CHEMICAL SYNTHESIS AND MANUFACTURING

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Abstract

The synthesis of metal oxide catalysts using the sol-gel method and their characterisation using various analytical techniques are the main subjects of this work. Several precursors, including tetraethyl orthosilicate, isopropyl alcohol, zirconyl nitrate hydrate, and ammonium heptamolybdate tetrahydrate, were combined to create the catalysts. In this investigation, X-ray diffraction (XRD) and Fourier-transform infrared spectroscopy (FT-IR) were used as characterisation methods. The catalysts' crystalline phases were identified, and their atomic scale properties were ascertained, using XRD analysis. The outcomes showed that the produced catalysts had tetragonal phase ZrO₂ and -MoO₃. By comparing the XRD patterns with reference data, the crystallinity and purity of the ZrO₂ phase were validated. The catalysts' molecular structures and functional groups were examined using FT-IR spectroscopy. The spectra showed distinctive peaks for Mo=O stretching, Zr-O-Zr asymmetric stretching, and Zr-O-O stretching. It was also proven that the catalysts contained the SiO₂ phase. The FT-IR data also showed that the strength and sharpness of the peaks, which represent changes in crystallinity, are affected by the temperature of the calcination process. Overall, the sol-gel approach was used to successfully synthesise metal oxide catalysts in this study, and their characteristics were determined using XRD and FT-IR methods. The findings shed important light on the catalysts' structural and textural characteristics, which are essential for comprehending how well they function as catalysts in a variety of processes.

Keywords: metal oxides, sol-gel method, catalyst synthesis, characterization techniques, X-ray diffraction.

1. INTRODUCTION

The worldwide economy has been slowly extending throughout the course of recent hundreds of years, and the synthetic area has been consistently advancing. The impending danger of the inaccessibility of numerous sustainable sources has been brought about by the impressive development in the serious climate and the critical decrease of the green assets [1]. Because of the broad utilization of substance innovation, the synthetic business has needed to manage critical clash on the destructive impacts on natural protection and feasible development. The productivity of the compound change has emphatically expanded because of various methodologies that have arisen in this space [2]. Compounds are the most possible green impetus to achieve the adjustment of bringing down the risky waste and helping the synthetic business draw nearer to a feasible and harmless to the ecosystem future among the different green methodologies now open. The enzymatic bio-catalysis process with green science to really address the obstruction of non-manageability It ordinarily utilizes harmless to the ecosystem strategies to make substance compounds, supplanting earth risky unrefined components and cycles with viable and harmless to the ecosystem approaches utilizing profoundly useful and specific enzymatic pathways, while limiting the requirement for extra filtration steps and the creation of unsafe waste during the change time frame [3]. By and large, the expression "green impetus" alludes to the utilization, recuperation, and going back over of compounds as biocatalysts. By bringing down the expense, raising the imminent proficiency, limiting natural openness, and supporting the arrangement of by and large technique supportability for the advancement of green science, they are actually accentuated for substance change [4]. The enzymatic bio-catalysis is a potential instrument for the turn of events and handling of the items as displayed [5] comparable to the 12 standards of Green Science. The significance of compounds relies heavily on how rapidly they can be delivered by a biocatalyst when contrasted with synthetic responses, and they can be created from inexhaustible sources such plants, creatures, and microorganisms [6]. The significance of enzymatic capacities is the motivation behind why numerous businesses, including synthetic, food, material, papers, biofuels, drugs, agribusiness, squander water treatment, medical care, and so on, are floating

towards bio-impetuses (either compounds or whole cells). Enzymatic methodologies wipe out the issues related with isomerization and revamp with high selectivity, action, and explicitness, prompting surges of finished results that are more unadulterated [7]. Furthermore, by showing chemo, locale, and sound system selectivity, bio-impetuses can definitely diminish the useful gathering enactment notwithstanding the drop in side-effect creation [8]. As displayed in the [9], different biopolymers are made principally on a modern scale from the bio-impetuses.

1.1.Green Chemistry and Environmental Sustainability

Green science (GC) is a technique for settling natural issues that considers the synthetic substances made as well as methodology or response stages. This technique is established on diminishing the creation and utilization of hurtful substances all through strategies [13]. The GC idea's space of substance gambles with covers a scope of dangers to human wellbeing and the climate, actual perils such as poisonousness, consumption of normal assets, and environmental change [14]. The objective of the GC is to examine the way that different synthetic standards may be utilized to the plan or blend of synthetics, subsequently limiting the creation or utilization of possibly destructive substances and saving the climate [15]. An extensive technique to safeguard the climate and human wellbeing should incorporate the GC. The GC is related with issues including diminishing waste at the source, utilizing safe reagents, impetuses, expanding monetary proficiency, utilizing sustainable assets, and utilizing solvents that are both protected and recyclable. The GC needs to make the working environment better for the two representatives and the climate. The idea of manageability was persuaded by natural disasters and stresses over asset consumption and substance defilement. The triple-primary concern hypothesis, which thinks about friendly, financial, and natural variables, is the underpinning of maintainability. This way of thinking underlined the need to adjust and add to the economy, society, and climate while completing turn of events. Planning human and modern frameworks reasonably includes ensuring that the utilization of regular assets and the human cycle doesn't bring down the worth of life and decrease ecological disparities. The demonstration of supporting the climate can appear as bringing down asset utilization, outflows, unsafe substance use, and natural disasters, as well as improving human wellbeing. Reasonable improvement is characterized as need might arise without endangering the capacity to meet those of people in the future. There are two fundamental ideas: (I) the idea of "needs"

for keeping up with human life; and (ii) the idea of cutoff points coming about because of the specialized and social states of the climate's ability to meet both present and future requests. Remarkable is the natural advantage of GC; how GS is done essentially works on the climate. Acknowledgment of GS might prompt decreased squander, less utilization of assets and energy, and less contamination. GS methods and items should be assessed to recognize likely wellsprings of tainting or contamination. These contaminations imperil the environment for our future through ozone depleting substance discharges, waste removal, and poisonous outflows from the handling of substances [16]. Plan for manageability in the compound business incorporate something other than wide innovative work drives at all degrees of science, process acceleration, and cycle update. Supportability has gotten far and wide endorsement as the fundamental objective of natural methodology.

2. LITERATURE REVIEW

To make ecologically dependable and economical cycles for synthetic union, the area of "green science" is extending. The production of green science processes for the union of natural mixtures has collected more consideration lately. The absolute latest progressions in this space will be analyzed in this writing review [17]. Decreasing the utilization of hazardous and poisonous substances in synthetic blend is one of the fundamental goals of green science. Making novel cycles for the amalgamation of natural mixtures utilizing non-harmful or inexhaustible feedstocks is one method for doing this. Developing interest has been displayed in involving biomass as a feedstock for natural combination lately. For example, it has been exhibited that lignin, a side-effect from the mash and paper industry, is a helpful wellspring of inexhaustible sweet-smelling compounds.

Making new, more naturally cordial response conditions is one more system for rehearsing green science [18]. For example, water is progressively utilized as a dissolvable since it is non-poisonous, effectively open, and safe for the climate. Furthermore, it has been exhibited that involving microwave light as a warming source is a more powerful and reasonable method for leading synthetic responses.

Green science endeavors to diminish squander creation as well as bringing down the utilization of hazardous synthetic substances and making novel response conditions. Making new reactant strategies that empower the particular union of explicit synthetics is one technique for

achieving this [19]. For example, it has been shown that utilizing change metal impetuses to specifically functionalize sweet-smelling particles is a proficient procedure to bring down how much waste delivered during the amalgamation interaction. Various novel procedures for the union of natural particles have been created because of ongoing huge progressions in the field of green science. These procedures might assist the substance business with creating economically and diminish the adverse consequences of synthetic amalgamation on the climate.

The Since strong acids are utilized in such countless various region of the compound business, they have become significant subjects. In the drug and processing plant businesses, where conventional, very destructive fluid acids like HCl, H₂SO₄, HF, BF₃, and AlCl₃ are utilized, strong corrosive impetus applications are critical. Different strong acids, for example, metal oxide, particle trade gums, and heterophony acids, have been utilized to supplant these acids. The benefits of strong corrosive impetuses incorporate their straightforwardness, simplicity of dealing with, decrease of reactor and impetus recovery plant consumption issues, and ecological wellbeing in removal. Strong acids have been utilized as the main thrust in countless substance union and change responses, contingent upon the corrosive strength and sharpness type [20].

Metal oxides assume a huge part in an assortment of physical, compound, and material logical disciplines. These particles structure a coordination circle around the metal particles and make a compacted structure because of the metal particles' tendency towards coordination. Scientists put a ton of accentuation on the attractive, optical, and surface properties of metal oxides since these properties are delicate to changes in design and structure [21]. Concentrates on this relationship assist us with appreciating the association better. Progress Researchers are focusing on metal oxides in light of their adaptable way of behaving and clear preparation strategy. Enterprises have utilized the d-block components and their subordinates as impetuses.

The utilization of progress metal oxides in heterogeneous catalysis, which is used to orchestrate a few natural particles by dehydrogenation, isomerization, specific oxidation, and other compound cycles, is perhaps of their most critical application. The comprehension of the science in view of these oxides is less evolved than that of metals and semiconductors, and less is had some significant awareness of the nuclear scale systems for synergist responses on

change metal oxides. For the impetus to be improved, this essential examination is required, especially the associations between the temporary oxides' synergist movement, their translucent designs, and the compound arrangements of their surfaces [22]. Delocalized electrons can be moved effortlessly in metal impetuses to make the redox synthetic response's cycle. To manage the surface properties, momentary metal oxides capability as ionic mixtures that are presented to different spots. Simultaneously, redox science turned out to be less critical because of the detachment of electronic states from the precluded band and diminished accessibility. Ionic oxides with higher hole become corrosive base impetuses, while metal oxides and semiconductors with lower restrictive groups permit a blend of redox science.

In a few compound cycles, progress metal oxides like CuMnCe, Mn-Ce-Zr, CuO-CeO₂, Au/CTN-silica, MoVTenb, Fe/CeO₂, Pt/CeO₂-MO_x, and so on have been utilized as impetuses. Zirconium oxide (ZrO₂) has drawn in interest throughout recent a very long time as both an upheld impetus (ZrO₂/LiO, ZrO₂/SiO₂, WO₃/ZrO₂, Ru/W/ZrO₂) and an impetus all alone. This is to a great extent since it has both corrosive and base destinations and is steady in both oxidizing and diminishing conditions. Earthenware production can be made utilizing zirconium oxide, which is utilized as a biomaterial. Because of its solid mechanical strength and protection from break, it has benefits over different earthenware production. To fix hard deformations, biomaterials have been recommended [24].

Zirconia additionally has different clinical purposes, including arthroplasty and dental crowns. Zirconium earthenware can be utilized for practical and underlying applications, despite the fact that zirconium and yttrium-settled zirconium oxide have muscular applications, for example, knee joints, hip joints, tibia platelets, impermanent backings, dental crowns, and solidified zirconia artistic froths that can be utilized in potential bone uniting applications [25]. ZrO₂ slim movies have favorable fired properties that make them reasonable for various specialized utilizes, including warm boundaries, optical coatings, catalysis, and reactant upholds. This part audits the writing on the utilizations of zirconium oxide and blended zirconium oxide in different spaces.

3. METHODOLOGY

3.1.Synthesis of Metal Oxides Using the Sol-Gel Method

The most common use of the sol-gel synthesis technique is the creation of metal oxides. The so-called sol-gel method is a process that can be used to create small-sized particles. The first step that must be completed for this process to be successful is the conversion of the source material into a colloidal solution. The first phase in creating a gel is known as "bringing together the individual particles," and it entails bringing the particles together one at a time. Precursors come in a wide variety of forms, with metal alkoxides and chlorides being the most common. There are two types of precursors: organic and inorganic. These precursors must first go through the hydrolysis process in order to form colloids, and then they must go through the polycondensation process.

3.2. Materials

Table 1 offers a list of all the substances that were applied during the catalyst production process. There was no need to perform additional purification on these compounds because they were all of an AR grade.

Table 1: Chemistry of Catalysts

S.no	Chemicals	Company
1	Tetraethyl Ortho silicate	98%
2	Iso-Propyl alcohol	52%
3	Zirconyl Nitrate Hydrate	23%
4	Ammonium heptamolybdate tetra hydrate GR	20%

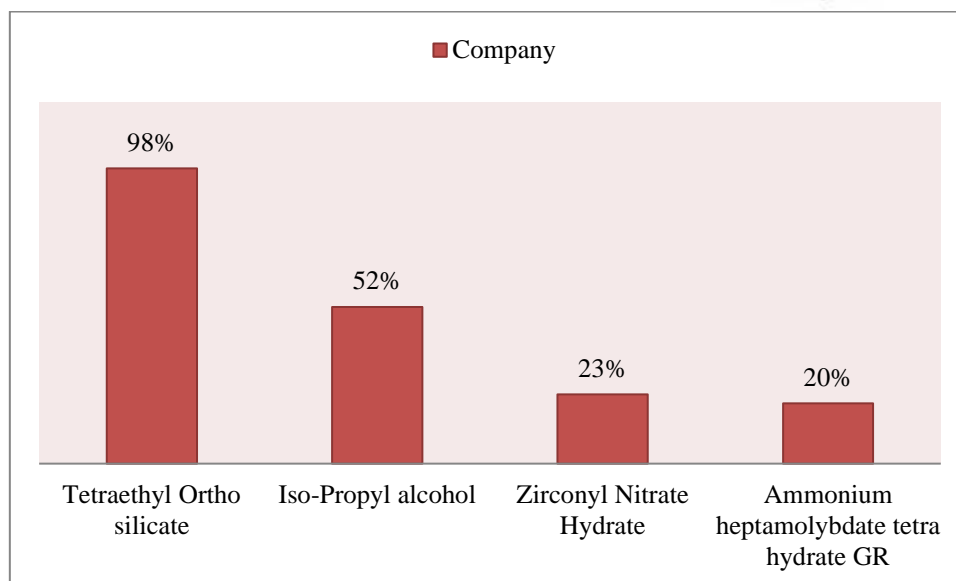


Figure 1: Catalyst-making chemicals

3.3.A Sol-Gel Approach to Catalyst Production

ZrO₂ upheld on MS with changing zirconium stacking (1, 5, 10, 15 and 20%) was arranged utilizing the sol-gel strategy. As hotspots for zirconium, molybdenum, and silica, individually, tetraethyl orthosilicate, zirconyl nitrate hydrate, and ammonium heptamolybdate tetrahydrate were utilized. As per a standard method, 1% ZrO₂/MoO₃/SiO₂ (1ZMS) was made by adding tetraethyl orthosilicate (40g) to isopropyl liquor (40ml), gradually consolidating with consistent blending, dissolving 24.6g of ammonium heptamolybdate tetrahydrate at all measure of water, and warming the combination at 800C for 30 minutes in a sonicator. Zirconyl nitrate hydrate (1.87g) was then dynamically added to the IPA arrangement with consistent blending, making a greenish gel create. This gel was then dried and calcined for 7 hours at 5000, 6000, and 7000 degrees Celsius. Zirconyl nitrate hydrate was utilized to make comparative impetuses with changed measures of 5%, 10%, 15%, and 20% ZMS.

3.4. Techniques of Characterization

3.4.1. X-ray Diffraction:

A huge examination in the portrayal of material, stage, and different variables like size and crystallinity is X-beam diffraction. By constrictive impedance of a monochromatic XRD bar at explicit points from grid planes in the example, the pinnacle is made. A central part of a

model XRD incorporates a x-beam source with a x-beam finder, the amount of a solitary precious stone, a set frequency, and the Scherer equation, which is utilized to figure the cross section strain and molecule size.

$$(t = 0.9\lambda \beta \cos \theta)$$

Where

T is the typical crystallite size.

In the x-ray diffraction pattern, is the location of the reflection.

x-ray wavelength is equal to.

= the reflection's whole breadth.

X-beam diffraction in light of the Bragg's condition's connection between the interplanar distance in the gem cross section, the electromagnetic radiation's frequency, and the point of diffraction

$$n\lambda = 2d \sin \theta$$

where n is the reflection order

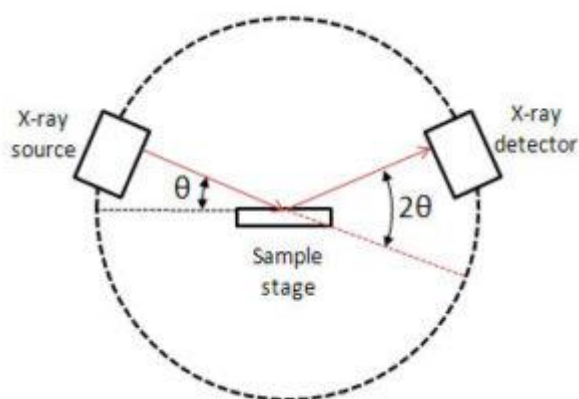


Figure 2: X-ray diffractometer schematic

Application:

X-ray diffraction is every now and again used to distinguish unidentified strong materials for examinations in geography and science that include material science, like inorganic mixtures and minerals. X-beam diffraction can likewise be utilized to portray translucent materials, recognize fine-grained minerals, decide precious stone construction, measure test virtue, describe glasslike materials, portray flimsy movies tests by deciding disengagement thickness and nature of the film, decide cross section bungle among substrate and film, decide thickness and thickness of the film, and measure unit cell aspects.

3.4.2. Fourier Transformation Infrared Spectroscopic Technique (FT-IR):

The use of infrared (IR) spectroscopy in catalytic research is crucial. The surface chemistry of nonhomogeneous catalysts can be assessed using this spectroscopic method very effectively. A potent tool for aiding in the molecular structure characterization of specific metal oxides is vibrational spectroscopy. To investigate surface metal oxides and their interactions with surface hydroxyls, FTIR can be utilised. The identification of various functional groups within the sample that absorb particular infrared radiation frequencies is the aim of FTIR spectroscopic investigation. FTIR spectrometers may accept a variety of sample types using various sampling accessories. The absorption peaks in the IR spectra, which correspond to the vibration frequencies between the atom bonds, serve as the specimens' fingerprints. Different materials have different atom combinations, hence it is impossible to precisely compare the IR spectra of two substances. As a result, the FTIR approach successfully identifies various types of material.

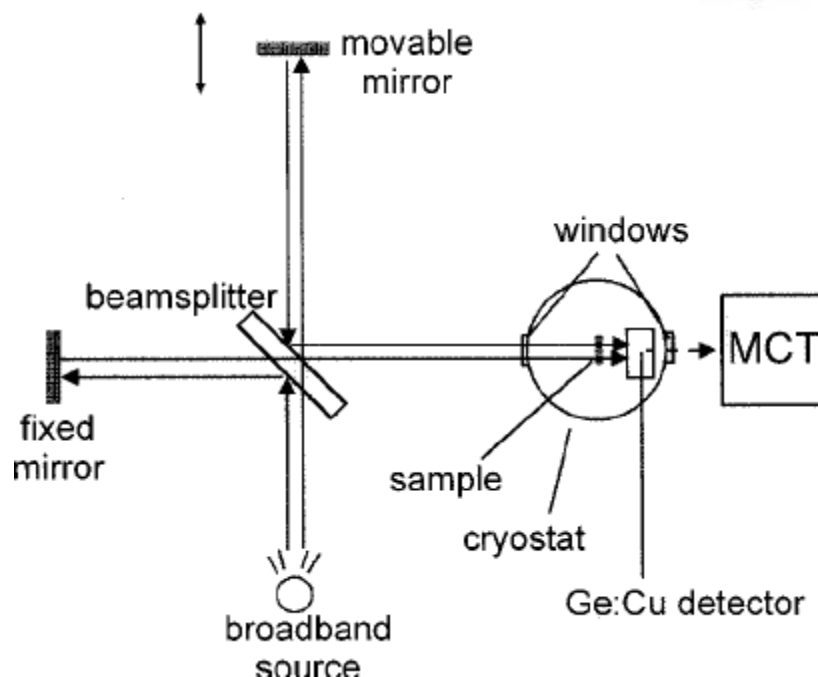


Figure 3: Schematic representation of FT-IR instrument

Application:

Both research and business use infrared spectroscopy extensively. FTIR spectroscopy is a straightforward and trustworthy tool for quality assurance and assessment; its main uses include the following:

Quantitative analysis is a helpful method for evaluating solid samples. It has the following advantages: substance identification, impurity detection, functional group and structure elucidation identification, reaction progress monitoring, and quantitative analysis.

It is possible to gauge the degree of polymerization using FTIR spectroscopy.

4. ANALYSIS AND RESULTS

By utilising several analytical techniques, this paper explains structural, textural, and morphological investigations of produced catalysts. X-ray diffraction investigations (XRD), Fourier Transformation Infrared Spectroscopic Technique (FT-IR), and other methods are used in the characterization process. By using various reactions, the produced nanocatalysts' surface acidity characteristics were evaluated.

4.1. X-ray Diffraction Technique (XRD)

The crystalline phases contained in synthesised catalysts were identified using the XRD patterns. Additionally, it was investigated to learn more about the atomic size of crystalline and amorphous materials. Figure 4 shows the XRD patterns of prepared pure ZrO₂, various ZrO₂ loadings on MoO₃ (1 wt% and 10 wt%), and various ZrO₂ loadings on MoO₃/SiO₂ calculated at 600, 700, and 800 °C.

The catalyst has diverse surface morphology, according to the results. The data set maintained by the Joint Committee on Powder Diffraction Standards (JCPDS) was used to identify the XRD phases found in the synthesised catalyst. Zirconia's XRD was also investigated for comparison purposes and is shown in Figure 5. All of the catalyst that had been synthesised had a very crystalline form. The tetragonal phase of ZrO₂ with planes (101), (110), (112), and (211) was represented by the intense peaks of the pure ZrO₂ catalyst at 30.220, 35.0, 50.310, and 60.120, respectively. When the ZrO₂ catalyst's XRD results were compared to the benchmark data (JCPDS File NO. 81-1545), the tetragonal phase was clearly visible and no other peaks were found. Pure zirconia oxide displayed distinctive peaks that nearly matched those of the standard. This demonstrated the outstanding purity and high degree of crystallinity of crystalline ZrO₂.

The crystalline phases contained in synthesised catalysts were identified using the XRD patterns. Additionally, it was investigated to learn more about the atomic size of crystalline and amorphous materials. The XRD patterns of produced pure ZrO₂, various ZrO₂ loadings on MoO₃ (1 wt% and 10 wt%), and various ZrO₂ loadings on MoO₃/SiO₂ calculated at 500°, 600°, and 700°C. The catalyst has diverse surface morphology, according to the results. The data set maintained by the Joint Committee on Powder Diffraction Standards (JCPDS) was used to identify the XRD phases found in the synthesised catalyst. All of the catalyst that had been synthesised had a very crystalline form. The tetragonal phase of ZrO₂ with planes (101), (110), (112), and (211) was represented by the intense peaks of the pure ZrO₂ catalyst at 30.220, 35.0, 50.310, and 60.120, respectively. When the ZrO₂ catalyst's XRD results were compared to the benchmark data (JCPDS File NO. 81-1545), the tetragonal phase was clearly visible and no other peaks were found. Pure zirconia oxide displayed distinctive peaks that

nearly matched those of the standard. This demonstrated that crystalline ZrO₂ possesses a high degree of crystallinity and exceptional purity.

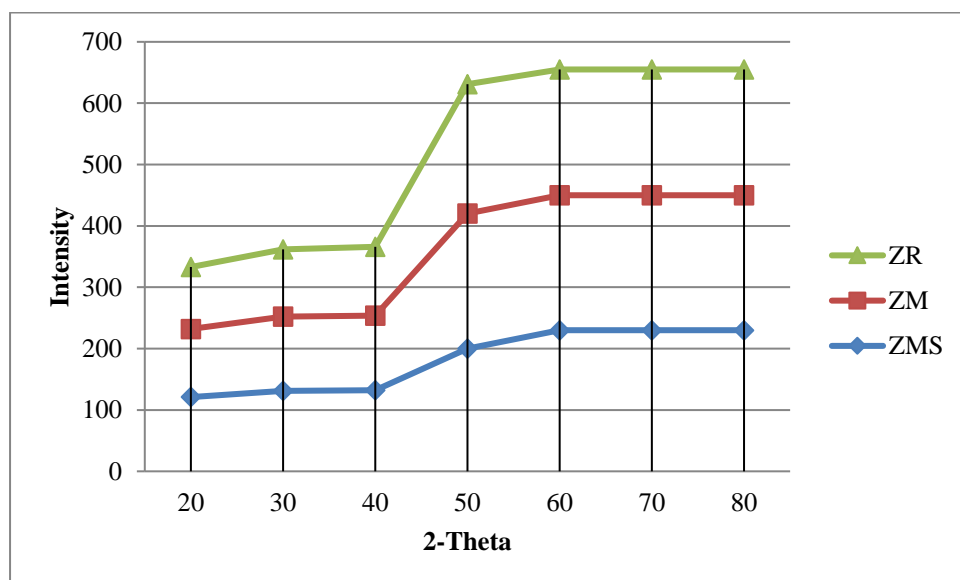


Figure 4: XRD pattern of 500°C-calcined pure ZR, ZM, and ZMS catalyst.

An active substance used frequently with supported oxide is MoO₃. The dispersion of the active phase, which is influenced by the method of preparation and the type of the supported oxide, determines the effectiveness of supported MoO₃ catalysts. Here, a ZrO₂/MoO₃ catalyst has been produced and characterised. ZM catalysts' XRD patterns were displayed in Fig. 5. Both 1ZM and 10ZM demonstrated the presence of zirconia's tetragonal and monoclinic phases and were consistent with published data. Compared to 1ZM, the peaks for 10ZM were less intense. It might be caused by a rise in zirconia on the support MoO₃.

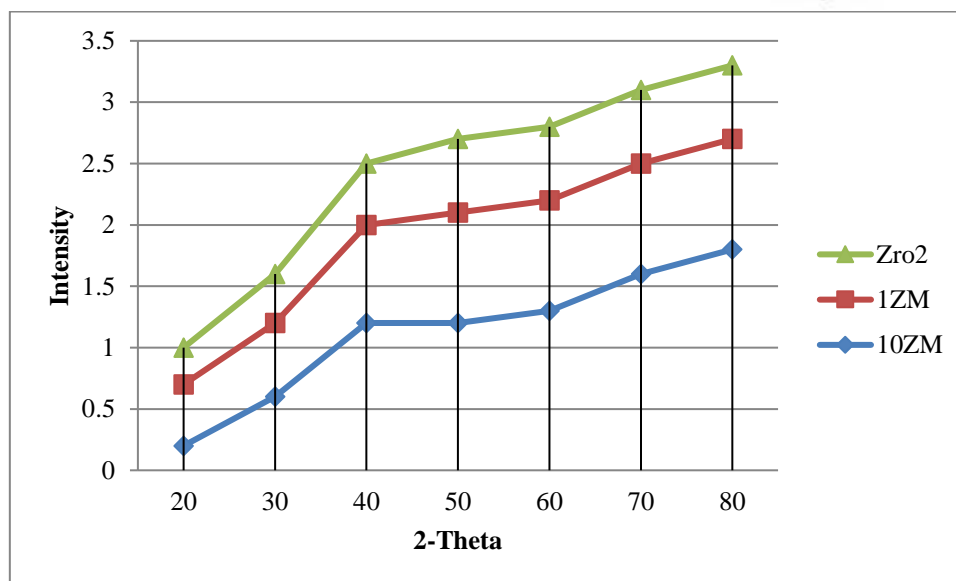


Figure 5: XRD pattern of 500°C-calcined ZrO₂ and ZM samples

MoO₃/SiO₂ blended oxide impetuses have gotten broad examination with respect to their primary and reactant properties since they are extremely dynamic impetuses in different cycles. Zirconia has been upheld on a MoO₃/SiO₂ impetus to expand the movement and selectivity of these impetuses. Unadulterated ZrO₂ and 1 wt% - 20 wt% ZrO₂/MoO₃/SiO₂ XRD designs. The integrated examples' noticed diffraction points concurred with the ordinary XRD designs. The orchestrated ZMS blended oxide impetuses had a particular top at 23.40, 25.80, 27.40, 33.70, and 49.60, which is connected with - MoO₃ on SiO₂ support. The tetragonal zirconia tops at 30.220, 350, 50.310, and 60.120 are apparent in ZMS blended oxide tests, regardless of the way that the silica support is of a shapeless structure. The creation of t-ZrO₂ across the outer layer of the MoO₃/SiO₂ support was affirmed by the obtained XRD tops. It was shown that as ZrO₂ levels expanded in ZMS tests, the pinnacles that relate to 30.22 and 50.31 showed an expansion in force and widened in shape. Subsequently, the typical crystallite size was diminished from 16.5 to 7.0 nm following the expansion of ZrO₂ on support MS impetus.

4.1.2. Fourier Transform Infra-red Spectroscopy (FT-IR)

A potent approach for identifying the molecular structures of supported metal oxides is infrared IR spectroscopy. This provides a sample fingerprint with absorption peaks that are in tune with the atomic bonds' vibrational frequencies. The images below show the FT-IR spectra of pure ZrO₂, different loadings of ZrO₂ supported on MoO₃, and MS catalysts that were calcined at

500-700 cm^{-1} . The KBr pellet technique was used to perform the FTIR measurements. FTIR spectra of ZR, 1ZM, and 10ZM samples are displayed in fig. 6. The production of ZrO_2 was confirmed by the FT-IR spectra of pure ZrO_2 , which had peaks at 740 cm^{-1} , due to Zr-O stretching modes and Zr-O-Zr asymmetric stretching. There were some overlapped peaks.

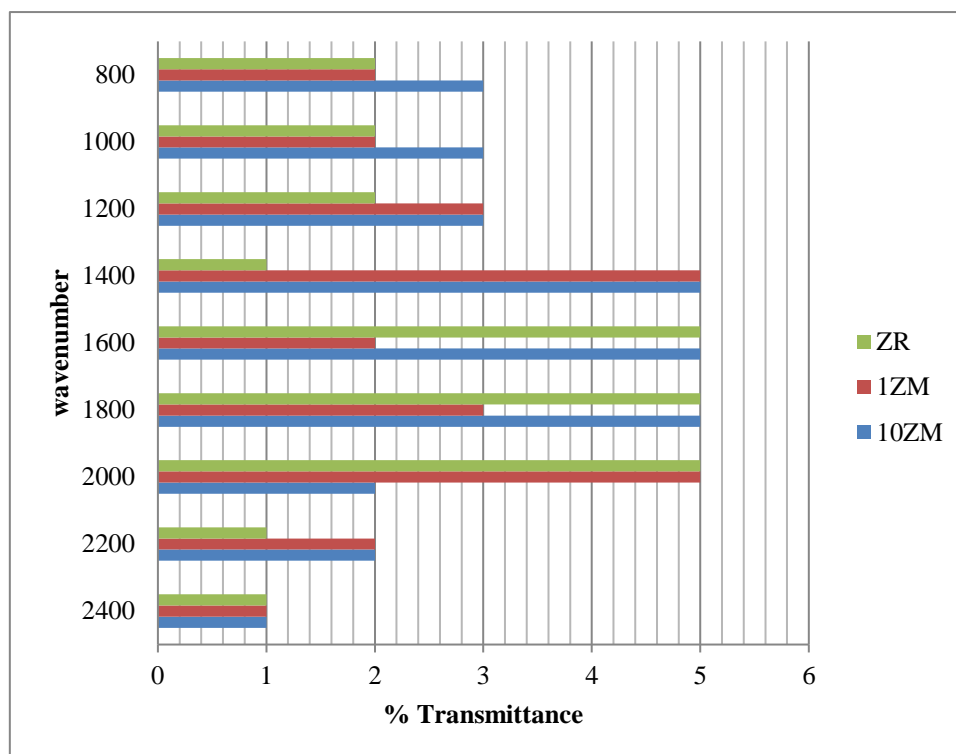


Figure 6: ZrO_2 and ZM FT-IR spectra

Figure 7 shows the FT-IR spectra of ZMS impetuses. Zr-O extending modes were credited to the bond at 1380 cm^{-1} and the top at 740 cm^{-1} , separately. Furthermore, the spectra uncovered a top for MoO at 1000 cm^{-1} . the top at 1097 cm^{-1} was credited to the Si-O-Si stretch that compared to the production of the SiO_2 stage, while the top at 608 cm^{-1} was connected with the O-Si-O twisting mode.

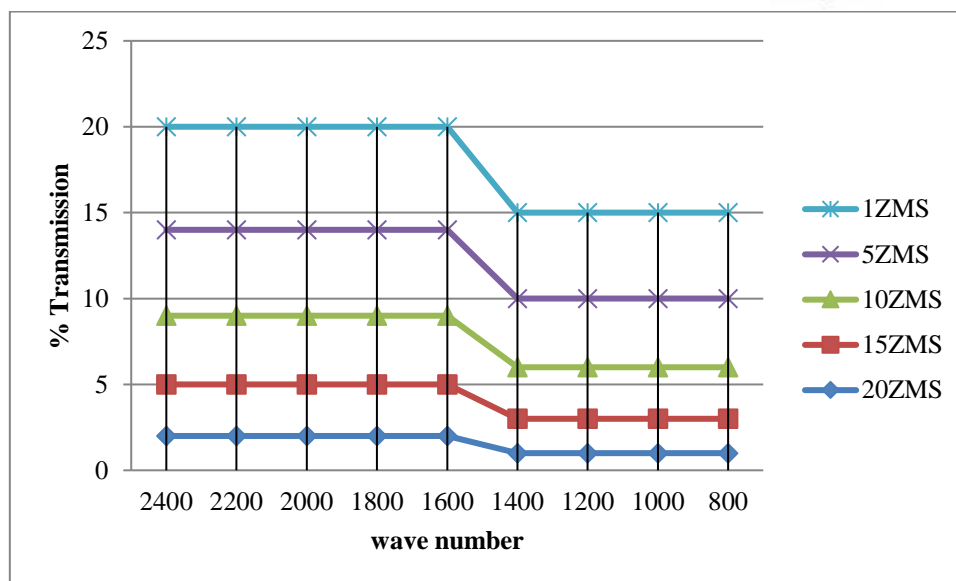


Figure 7: FT-IR Spectra of various % ZMS calcined at 500°C

At 600, 700, and 800 °C, prepared samples' FT-IR values were asserted. Figure 8 shows the FT-IR spectra of ZrO₂ calcined at various temperatures. After high-temperature calcination, it was noticed that the peaks became sharper, which indicated an increase in crystallinity.

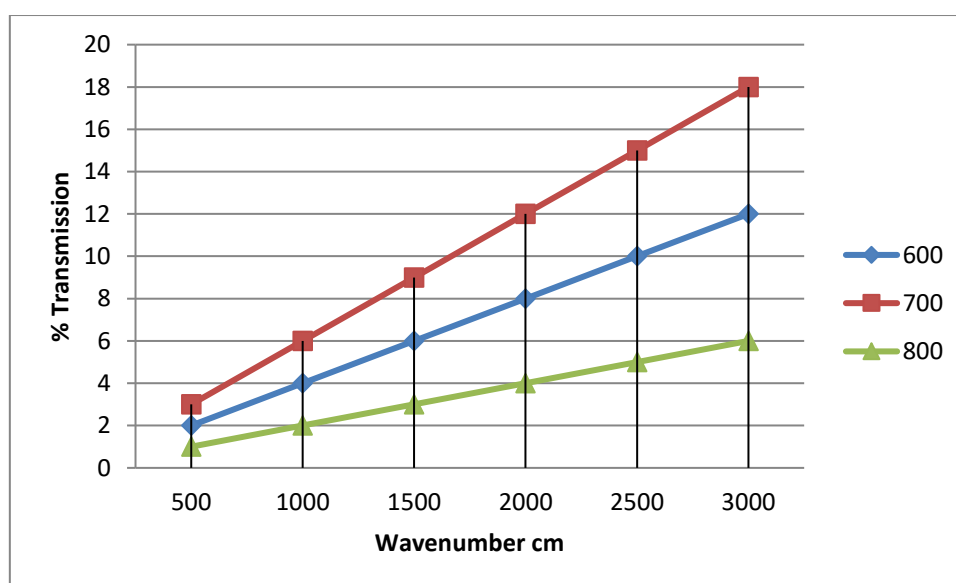


Figure 8: Temperature-dependent ZrO₂ FT-IR spectra

Figure 9 shows the FT-IR spectra of a 1ZM impetus that was calcined at 600, 700, and 800 C. As the temperature expanded, the force of tops at 870 and 1000 cm⁻¹ that relate to - MoO₃

diminished. It was likewise seen that tops that relate to Zr-O extending zirconia in the examples at low stacking, or 1 wt.% ZrO₂ on MoO₃, vanished.

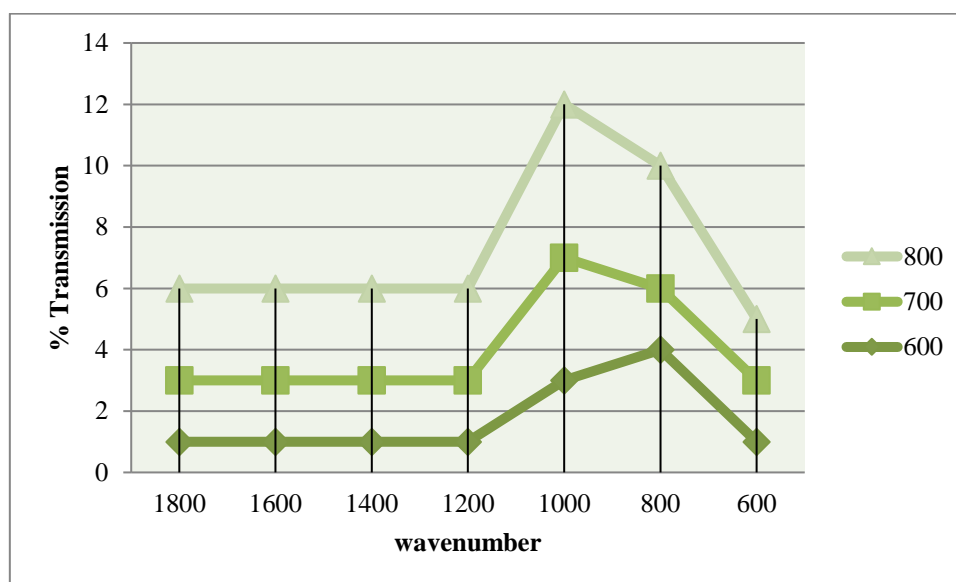


Figure 9: FT-IR spectra of 1ZM at various temperatures.

Conclusion

In this review, the sol-gel strategy was utilized for the amalgamation of metal oxides, specifically zirconia (ZrO₂), molybdenum oxide (MoO₃), and silica (SiO₂). The fixings utilized in the amalgamation, including tetraethyl orthosilicate, isopropyl liquor, zirconyl nitrate hydrate, and ammonium heptamolybdate tetrahydrate, were of logical reagent (AR) grade and didn't need additional filtration. The sol-gel strategy was applied to blend ZrO₂ upheld on MoO₃/SiO₂ impetuses with shifted ZrO₂ loadings (1%, 5%, 10%, 15%, and 20%). The procedure required the sluggish expansion of tetraethyl orthosilicate in isopropyl liquor, trailed by the expansion of broken down ammonium heptamolybdate tetrahydrate and zirconyl nitrate hydrate. A greenish gel was made, which was therefore dried and calcined at different temperatures. The delivered impetuses were described utilizing a few methods. X-beam diffraction (XRD) assessment was embraced to identify the glasslike gradually works present in the impetuses. The XRD designs demonstrated the presence of tetragonal ZrO₂ and α -MoO₃ on the impetus surfaces. The typical crystallite size was found to diminish with expanded ZrO₂ stacking. Fourier change infrared spectroscopy (FT-IR) was applied to investigate the atomic designs of the impetuses. The FT-IR spectra showed unmistakable pinnacles comparing to Zr-

O extending modes, Zr-O-Zr deviated extending, Mo=O extending, and Si-O-Si stretch, exhibiting the amalgamation of the ideal metal oxides.

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