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Review Article

The New Era of Synthesis: Greener Chemistry with Microwave Technology

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ABSTRACT

Microwave Assisted Synthesis (MAS) has become as a revolutionary approach in green chemistry, giving an energy efficient, environmentally friendly alternative to traditional synthesis technique can reduces the time of reaction from hr to min. Conventional method of synthetic reactions needs longer heating, high solvent consumption, & significant chemical waste. This review aims to introduce MAS as an eco-friendly technique that outstanding faster reaction rates, improved practical yields, enhances reaction effectiveness by selectively heating the reaction mixture, and reduced byproducts formation. This technique complies with the principles of green-chemistry by reducing toxic solvent use and optimizing reaction conditions for sustainability. The mechanisms of microwave heating, including dipolar polarization (rotation of polar molecules) and ionic conduction (movement of ions), enable specific and uniform energy transfer, making it an effective tool for various chemical transformations. Additionally, strategies for calculating the required temperature, power, and time under microwave conditions are also offer to achieve reproducible and efficient results.

INTRODUCTION

For centuries, conventional heating methods such as Bunsen burners, oil baths, and heating mantles have been used to carry out chemical reactions. However, these techniques are time-consuming, often requiring long reaction times, and are energy-inefficient and wasteful. They can also create localized hot spots on the surface of reaction vessels, leading to the decomposition of reagents and the formation of toxic by-products. Additionally, these methods frequently involve the use of solvents that are toxic, environmentally harmful, and require extra steps for their removal and disposal [1].The concept of Green Chemistry is comes to designing chemical products and processes that aim to minimize or eliminate the use

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and generation of hazardous substances. The term was introduced by Paul Anastas and John Warner in the 1990s while working as a staff chemist at the U.S Environmental Protection Agency (EPA) [2], Green Chemistry is defined as the application of a set of principles aimed at minimizing or avoiding the use and production of hazardous substances throughout the design, manufacturing, and use of chemical product [3]. Twelve principles of Green Chemistry: 1. Prevention: Preventing waste is more effective than dealing with it after it's created. 2. Atom Economy: Maximize the combining of all starting materials into the final product. 3. Less Hazardous Chemical Syntheses: Use and generate substances with minimum toxicity. 4. Designing Safer Chemicals: Chemical products should be designed to be less toxic wherever possible. 5. Safer Solvents and Auxiliaries: Solvent use should be minimized or eliminated whenever possible. 6. Design for Energy Efficiency: Conducting chemical reactions at lower temperatures and pressures helps reduce energy consumption. 7. Use of Renewable Feedstocks: Use renewable raw materials instead of non-renewable resource. 8. Reduce Derivatives: Avoid unnecessary derivatization steps like blocking or protecting groups. 9. Catalysis: Use selective catalytic reagents over of stoichiometric reagents. 10. Design for Degradation: Design products that break down into harmless substances after use. 11. Real-time Analysis for Pollution Prevention: Analyse chemical processes in real-time to prevent hazardous product formations. 12. Inherently Safer Chemistry for Accident Prevention: Choose substances and their forms to minimize chemical accidents (e.g., fires, explosions) [4].

Microwave: Microwave Assisted Synthesis (MAS) is considered as a “green chemistry” Microwave synthesis is as an important approach toward green chemistry, because this technology is more eco-friendly. Due to its ability to couple directly with the reaction molecule and by-passing thermal conductivity leading to a rapid rise in the temperature, microwave irradiation has been used to improve many synthesis [5]. The ability of microwaves to heat matter was discovered accidentally in the 1940s by an American engineer named Percy Spencer while working for the Raytheon Company on magnetrons for radar sets. Spencer noticed that a candy bar in his pocket melted when he was standing near an active radar set, realizing the heating power of microwaves.

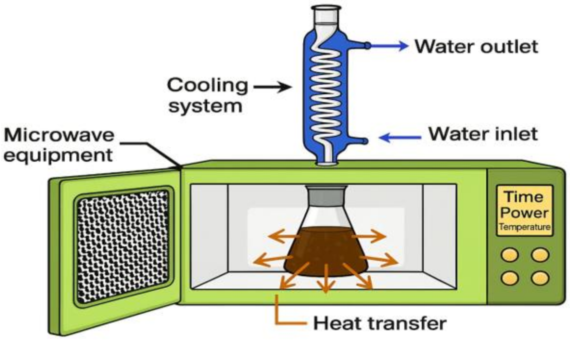


FIG.NO.1 Microwave Synthesizer [6]

The first commercial microwave oven, the "Radarange" was introduced by Raytheon for food processing in market and the first domestic microwave oven was introduced by Tappan in 1955 but in 1970s frequently used domestic microwave oven comes [7]. The shift from kitchen to lab happened in the mid-1980s when scientists Richard Gedye and Gilles Giguere independently published pioneering work demonstrating that household microwave ovens could significantly accelerate common organic reactions (e.g., Diels-Alder, Claisen rearrangement) from hours to minutes. In the late 1990s with the introduction of dedicated, pressurized microwave reactors. These specialized instruments provided precise control over temperature and pressure, ensuring safety and reproducibility. Led by C.Oliver Kappe and others, this innovation established MAS as a crucial, time-saving, and environmentally friendly methodology in modern synthetic and pharmaceutical chemistry, fulfilling the principles of Green Chemistry by offering faster reactions and higher yields [8]. Microwaves are a form of electromagnetic energy with frequencies ranging from 300 Megahertz (MHz) to 300 gigahertz (GHz). The commonly used frequency is 2.45 gigahertz (GHz) and wavelengths between approximately 1 cm and 1 m.

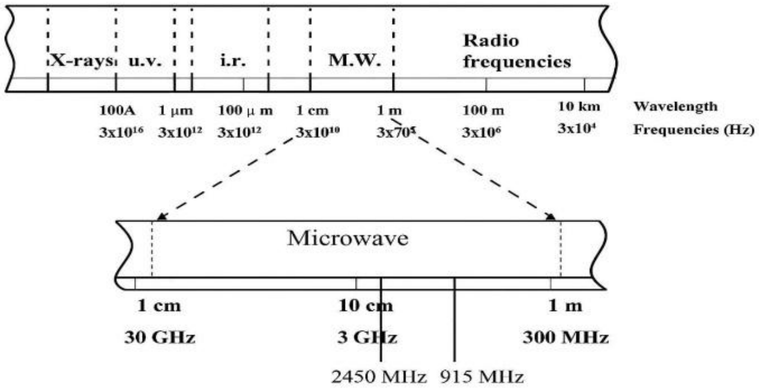


FIG.NO.2 Location of microwave on the electromagnetic spectrum.

Principle of Microwave-Assisted Synthesis: Microwave assisted synthesis is based on the principle of dielectric heating, where microwave radiation (2.45 GHz) interacts with polar molecules and ions in the reaction mixture. The oscillating electromagnetic field causes dipolar polarization (rotation of polar molecules) and ionic conduction (movement of ions), generating heat uniformly and rapidly within the material. This direct molecular-level heating accelerates reaction rates compared to conventional methods. [9]

Mechanism of Microwave Heating: Not all materials or molecules reacts the same way to microwave radiation different substances react differently. Based on how they interact with microwave radiation, materials can be distinguished into three main categories: 1. Microwave-transparent materials: These substances do not absorb microwave radiation and remain unaffected. Such as-Sulphur. 2.Microwave-reflective materials: These substances reflect microwave radiation. Such as-Copper. 3. Microwave-absorbing materials: These absorb microwave energy and convert it into heat. Such as- Water. In microwave-assisted chemistry, the third category- microwave absorbing materials is most important [10]. The entire mechanism of microwave-assisted synthesis (MAS) is based on the ability of microwave radiation is a form of electromagnetic energy to transfer energy directly to the molecules within a reaction mixture. This process is basically different from conventional heating, which relies on conduction and convection. The direct energy transfer occurs primarily through two mechanisms namely: Dipolar Polarization and Ionic Conduction.

1.Dipolar Polarization: Dipolar polarization is the phenomenon responsible for the most of microwave heating. It depends upon nature (polarity) of solvent and compound. For a substance to heat under microwave radiation, it must have a dipole moment (which means its molecular structure must be partly negatively and positively charged). Since the microwave field is oscillating, the dipoles in the field align to the oscillating field. When microwaves hit a polar molecule (like water, methanol or ethanol), the molecule tries to align itself with the rapidly changing electric field. This repeated reorientation leads to molecular friction, due to this friction dipoles lose energy in form of heat. For dipolar polarization to be effective, the microwave frequency must be appropriate. If the of radiation is too high, the molecules can't move fast enough to follow the field, decreasing heating. In this condition, no motion so no heating occurs [11].

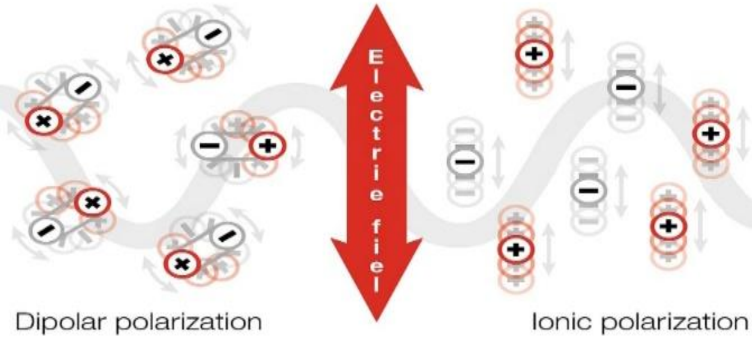


FIG.NO.3 Dielectric heating mechanism of dipolar polarization and ionic conduction

2.Ionic Conduction Mechanism: When an electric field from the microwave interacts with a conductive material (like a solution containing ions). In this phenomenon, these ions oscillate back and forth that causes ions collide with each other and generate the heat. This mechanism provides a better heat-releasing capacity than the dipolar rotation mechanism. If there are free ions in the reaction mixture, these ions try to orient in the direction of applied electric field due to ionic motion and cause the instantaneous superheating [12]. E.g., if same amount of distilled water and tap water are heated in microwave irradiation, faster heating will occurs for tap water because of its ionic content in addition to the dipolar rotation of water molecules [13].

Microwave-Assisted Chemical Reactions Types:

1)Dry media synthesis: It is a most common microwave method. In that high pressure and associated danger of explosion in solvent mediated sealed container can be avoided by dry media or solvent free synthesis. It includes neat reaction and solid-support reactions. (a) Neat reaction: It refers to reaction carried out without using solvent. A mixture of reactants without the use of solvent helps to avoid the risk of developing high pressure and explosion. (b) Solid-support reactions: A reaction can be carried out by adsorbing the reactants on an inorganic solid support under microwave irradiation. Inorganic solids namely in clay, silica, alumina and Zeolite are commonly useful solid supports (catalysts). The reactants adsorbed on the surface of inorganic solids absorb the microwave radiation.

2)Solvent mediated synthesis: High boiling polar solvents such as N,N-dimethyl formamide, odichlorobenzene, 1,2 dichloroethane useful in the microwave reactions. Polar solvents with a high dielectric constant absorb microwave energy better than non-polar solvents due to dipole rotation. These solvents offers higher energy transfer rates. Water is an ideal solvent since it fulfils many criteria; non-toxic, non-inflammable and abundantly available and inexpensive. It gives high polar character, novel reactivites and selectivities.

Effect Of Reaction Parameters In Microwave Assisted Synthesis: Microwave-assisted synthesis (MAS) is a rapid and energy-efficient method that depends strongly on several operative parameters. Included solvent, temperature, irradiation time and microwave power are the most important in determining the rate of reaction, morphology and yield of the final product.

1. ***Solvent:*** Solvent play a very important role in synthesis. Most reaction take place in presence of solvent, and therefore, choice of solvent can be a critical factor in the outcome of a reaction. One of the most important characteristics of solvent is its polarity. The solvents used in microwave reaction should possess dielectric property (tan δ) that determine how well it match with microwave field (i.e., how much microwave energy is absorbed and convert to heat). The solvent with high tan δ provide rapid heating. However, the solvent with low tan δ also can be used, but provide slow heating.

Table 1: Microwave solvent along with their dielectric constant values [14]

Power	**Temperature**	
	In degree Celsius(°C)	**In Watts**
90-100	220-260	900 (100%)
80	190-220	600(67%)
70	175-190	600(67%)
50-60	150-175	450(50%)
30-40	110-150	300(33%)
20	90-100	180(20%)
10	65-90	100(11%)

2) Temperature: Temperature is a critical aspect that control the kinetics of microwave-assisted reactions. In MAS, heat is generated internally within the reaction medium by the interaction of the microwave field with polar molecules or ions, resulting in volumetric heating. As the temperature increases, molecular vibration and collision frequency also increase, leading to faster reaction kinetics and accelerated nucleation. Bases on "Arrhenius law" According to law, when the reaction temperature increased by 10°C, the reaction time half. Example: A reaction that is performed in boiling of ethanol (approx. at 80 °C) within 8 hours can be performed at 160 °C in approximately 2 minutes.

Table 2: Approximate time saving aspect according to Arrhenius' Law [15].

Reaction Temperature	80°C	90°C	100°C	110°C	120°C	130°C	140°C	150°C	160°C

Reaction Time	8 h	4 h	2 h	1 h	30 min	15 min	8 min	4 Min	2 min

3) Irradiation time: Irradiation time refers to the duration for which the reaction mixture is exposed to microwave energy. It directly affects the degree of reaction completion and the physical characteristics of the synthesized product. At short irradiation times, insufficient energy transfer leads to incomplete conversion and poor crystallinity. So, synthesis start with a very short duration (e.g., 5-10 min) and gradually increase until conversion is maximized, minimizing the overall thermal stress on the product and is monitored by chemical analysis technique (e.g. TLC, HPLC, GC) during trial runs. The duration of the microwave heating can be optimization depending upon the reaction nature and instrument (model). Reaction kinetics accelerated under microwave conditions (Arrhenius-based energy activation) given by Svante Arrhenius (1889) [16]. $\mathbf{k = Ae^{-Ea/ET}}$

4) Power (Wattage): Microwave power is amount of electromagnetic energy delivered to the reaction mixture per unit of time. Power is determines how fast the reaction mixture absorb the microwave radiation and converts it into heat. Microwave power has direct influence on the reaction progress and rate of reaction. The exothermic nature of the reaction decides the power requirement for synthesis. Hence, chemical reactions like dehydration require high power. In that, different instruments use different magnetron and their capacity slightly different form each. This decides the power levels to be set for given reaction.

TABLE 3: The most general power set up is given as:

Strategies for calculating required temperature, power and time parameters

1. Power Density [17]***:*** Defines the rate of energy absorbed per unit volume in a material. Depends on microwave frequency, dielectric properties, and electric field strength. The power density of microwaves in a dielectric material is given by Metaxas and Meredith (1983): $\boldsymbol{p = 2\pi f \varepsilon_0 \varepsilon'' E^2}$ or, $\boldsymbol{p = 2\pi f \varepsilon_0 \varepsilon'' \tan\delta E^2}$

Where,

- p=Volumetric power density ($W \cdot m^{-3}$)
- F= Microwave frequency (Hz)
- ε_0= Vacuum permittivity (8.854×10^{-12} $F \cdot m^{-1}$)
- ε'= Dielectric constant
- ε'' = Dielectric loss factor
- $\tan\delta = \varepsilon''/\varepsilon'$ = Loss tangent
- E^2= Electric field strength ($V \cdot m^{-1}$)

Use in optimization: Increasing E or tanδ increases the power density, For materials with low dielectric loss, heating is slower; high dielectric-loss materials heat more fastly, Can be used to estimate required power input to achieve target heating rates.

2. Absorbed Power from Calorimetry: Measures actual energy absorbed by the sample based on temperature rise, Calculated as: $\mathbf{p_{abs} = mC_P(dT/dt)}$

Where,

- p_{abs} = absorbed power (W)
- m = sample mass (kg)
- C_P= specific heat capacity ($J \cdot kg^{-1} \cdot K^{-1}$)
- dT/dt = initial temperature rise rate ($K \cdot s^{-1}$)

Use in optimization: Measures the real energy absorbed by the sample, which may differ from the theoretical power density, Can be used to correct microwave power settings to avoid overheating or low-heating.

3. **Coupling Efficiency** [18]**:** Derived from Fourier's law of heat conduction, in 1822. Required heating time to reach a target temperature is estimated as, $\mathbf{t = mC_p \frac{\Delta T}{p_{abs}}}$

Where,

- t = heating time (s)
- p_{abs} = absorbed power (W)
- C_P= specific heat capacity (J·kg^{-1}·K^{-1})
- $\triangle T$=T_{target}-T0(initial) (K)

Use in optimization: Provides the required heating time for a known absorbed power, Can also be inverted to calculate required absorbed power for a desired heating time of material.

4. Specific Absorption Rate (SAR): Power absorbed per unit mass given by Herman P. Schwan (1953), $\boldsymbol{SAR = {p_{abs}}/{m}}$

TABLE 4: Properties of water

Property	Value
Dielectric constant, ε′	78.4 (at 25 °C)
Dielectric loss factor, ε″	12.3 (at 25 °C)
Loss tangent, tan δ	ε″ / ε′ ≈ 0.157
Density, p	1000 kg/m³
Specific heat, C_p	4184 J/kg·K
Mass, m	Assume 0.1 kg (100 mL water)

Use in optimization: Useful for comparing heating efficiency across different sample sizes, Can be linked with power density. ***Example****:* Parameters for water during microwave-assisted heating. Assume typical lab microwave conditions**:** 2.45 GHz, room temperature initial (25 °C), and target temperature 80 °C [22].

Microwave frequency: f=2.45 GHz = $2.45\times10^9\ Hz$ GHz=2.45×109Hz
Vacuum permittivity: ε_0= $8.854\times10^{-12}\ {F}/{m}$

1. Power Density (p): $\boldsymbol{p = 2\pi f \varepsilon_0 \varepsilon'' tan\delta E^2}$

p= 2π (2.45×10^9) (8.854×10^{-12}) (78.4) (0.157) (1000^2) = Power density: **≈ 1.67 MW/m³**

2. Absorbed Power from Calorimetry: $\boldsymbol{p_{abs} = mC_P(dT/dt)}$

p_{abs}= 0.1×4184×2 ≈ **836.8 W** = Absorbed power: **≈ 837 W**

3. Heating Time (t): Target ΔT = 80 °C – 25 °C = 55 K $\therefore \boldsymbol{t = mC_p \frac{\Delta T}{p_{abs}}}$

$= \frac{0.1 \times 4184 \times 55}{836.8} \approx 836.823012 \approx$ **27.5 s** = Estimated heating time: **≈ 28 s to reach 80 °C**

4. Specific Absorption Rate (SAR): $\boldsymbol{SAR = p_{abs}/m} = \frac{836.8}{0.1} = 8368$ W/kg

SAR: ≈ **8.37 kW/kg**

TABLE 5: RESULT OBTAIN FOR WATER

Parameter	**Value**
Power density, p	1.67 MW/m³
Absorbed power	837 W
Heating time, t	28 sec
SAR	8.37 kW/kg
ΔT	55 K

MICROWAVE V/S CONVENTION SYNTHESIS: Conventional synthesis usually involves the use of a furnace or oil bath which heats the walls of the reactors by convection or conduction. The core of the sample takes much longer to achieve the target temperature. In microwave-assisted synthesis (MAS), microwave penetrates inside the material and heat is generated through direct microwave and material interaction.

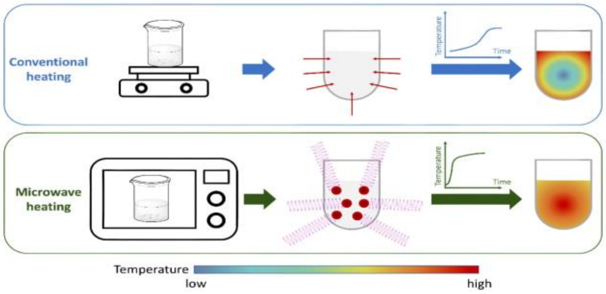
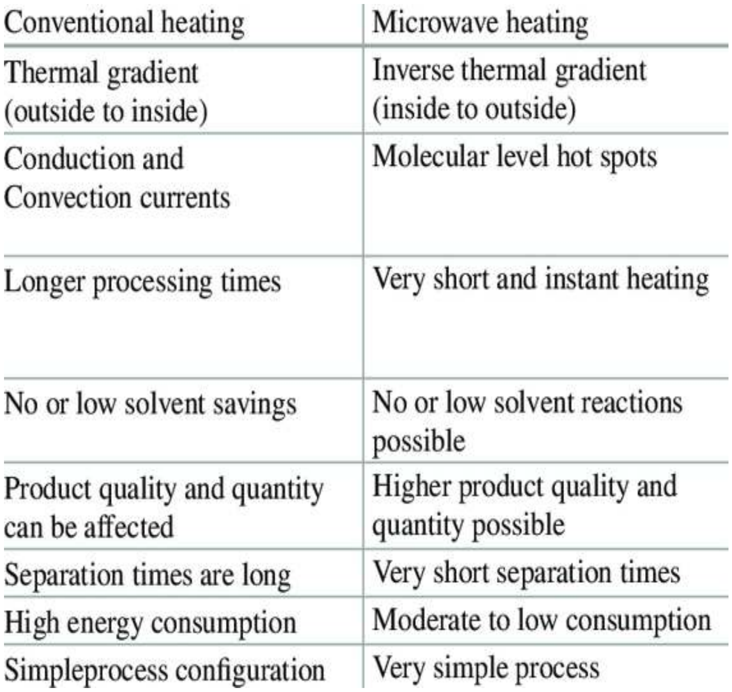


FIG.NO.4 Comparison of microwave heating v/s conventional heating

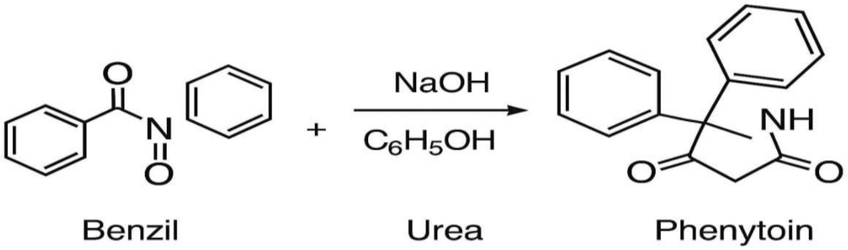
TABLE 6: MICROWAVE V/S CONVENTION SYNTHESIS [20].



Conventional heating	Microwave heating
Thermal gradient (outside to inside)	Inverse thermal gradient (inside to outside)
Conduction and Convection currents	Molecular level hot spots
Longer processing times	Very short and instant heating
No or low solvent savings	No or low solvent reactions possible
Product quality and quantity can be affected	Higher product quality and quantity possible
Separation times are long	Very short separation times
High energy consumption	Moderate to low consumption
Simpleprocess configuration	Very simple process

Comparative Study Of Conventional V/S Microwave Synthesis:

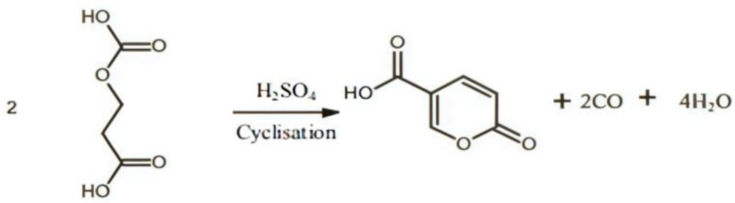
I) Synthesis of Phenytoin [21]*:*



Conventional Synthesis: A mixture of 5.3gm of benzyl, 3gm of urea, 15 ml of 30% aq. sodium hydroxide (NAOH) and 25 ml of ethanol was taken in a 100 ml round bottomed flask. The reflux condensation was carried out for 2 hr. Then, the mixture was cooled to room temperature and the solution was poured into 125 ml of water, mix thoroughly and allowed it to stand for 15 minutes. Then, the solution was filtered under suction and filtrate was made strongly acidic with concentrated HCL acid, cooled in ice water, filtered and recrystallized from ethanol.

Microwave Synthesis: A mixture of 5.3gm of benzyl, 3gm of urea, 15 ml of 30% aq. NAOH and 25 ml of ethanol was taken in a beaker. The beaker was then placed in a microwave oven at 190 watts for 6 minutes. Then, the mixture was cooled to room temperature and the solution was poured into 125 ml of water, mix thoroughly and allowed it to stand for 15 minutes. Then, the solution was filtered under suction and filtrate was made strongly acidic with concentrated HCL acid, cooled in ice water, filtered and recrystallized from ethanol.

II) Synthesis of Coumalic acid:

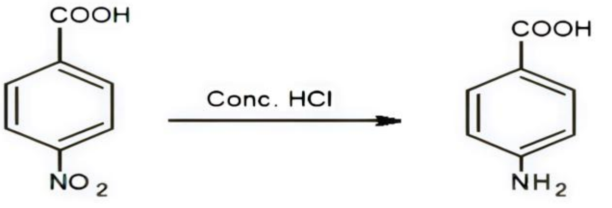


Malic acid **Coumalic acid**

Conventional Synthesis: Take 25 ml of sulphuric acid was added to 20gm of finely powdered malic acid which was taken in a 2 litre round bottomed flask. Three 15 ml portions of fuming sulphuric acid (25% So3) was added at intervals of 45 min. A slight exothermic reaction occurred with the steady evolution of gas. Then the mixture was shake frequently to prevent excessive foaming and when the evolution of gas had release, the reaction mixture was heated on a water bath for 2 hours. Then the mixture was cooled and poured into 80gm of ice with stirring. The mixture was then kept aside in a refrigerator for 24hr, filtered the crude coumalic acid and washed with small portions of ice water. The crude product was recrystallized from methanol.

Microwave Synthesis: A mixture of 2gm of malic acid with 4 ml of concentrated sulphuric acid was added with 3 portions of 1.5 ml of fuming sulphuric acid with 45 minutes time interval. Then the beaker was placed in a domestic microwave oven at 250 watts for 4 minutes. Then, adequate amount of ice was added and kept in the refrigerator for about 24hr. The product was filtered and recrystallized from methanol.

III) Synthesis of P-amino benzoic acid:

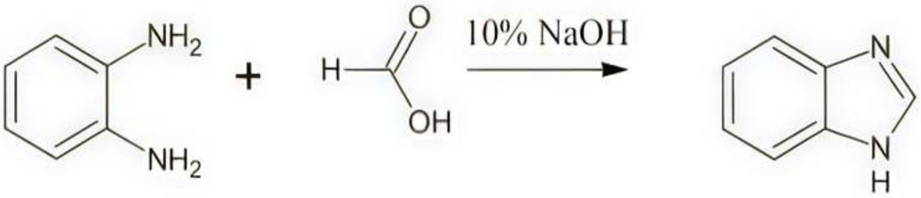


p-nitrobenzoic acid p-aminobenzoic acid

Conventional Synthesis: In a 250 mL round-bottom flask add 3.00 g p-nitrobenzoic acid and 30–50 mL ethanol and stir to dissolve. Add 4gm powdered to the flask and slowly add 8 mL conc. HCL drop wise with stirring. Control temperature keep ≤70 °C then reflux the mixture for 30–60 min. Monitor by TLC; reaction is complete when starting spot disappears. Cool to room temperature and filter it. Wash solids with warm ethanol. Slowly alkalize the combined filtrate with concentrated NH_3 solution until just alkaline to litmus product will precipitate. Collect the solid by suction filtration, wash with cold water, and dry.

Microwave Synthesis: Place 3g of p-nitrobenzoic acid in a 250m l round bottom flask and introduce 4gm powered tin and 8ml conc. HCl. Irradiate the mixture under microwave, 225 watt for 3 min. Shake the flask frequently; occasional gentle warming may be necessary. After about 5 min, most of the tin will have reacted and a clear solution remains. Allow to cool and add conc. ammonia solution until the solution is just alkaline to litmus. Filter off solid with Buchner funnel ad allow the product to dry. M.pt: 185-187◦C.

IV) Synthesis of Benzimidazole:

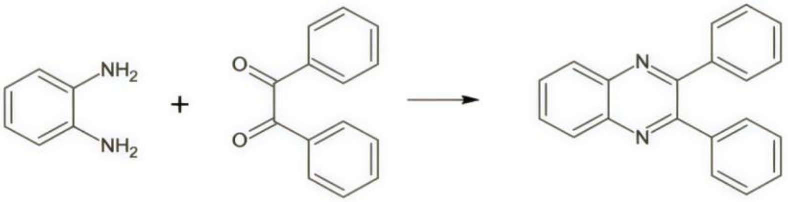


O-Phenylene Diamine **Formic acid** **Benzimidazole**

Conventional Synthesis: In a 250 ml round bottom flask fitted with a condenser, a mixture of 27gm of O-Phenylene diamine and 17.5gm (16 ml) of 90% formic acid was refluxed thermally at 100°C for 2 hours. The reaction mixture was cooled and 10% NAOH solution was added slowly, then the crude product was washed with ice cold water, dissolved in 400 ml of boiling water for recrystallization, filtered and dried at 100°C.

Microwave Synthesis: In a conical flask a mixture of 27gm of O-Phenylene diamine and 17.5gm (16 ml) of 90% formic acid was taken. Then the conical flask was placed in a microwave oven at 100 watts for 6 minutes. The reaction mixture was cooled and 10% NAOH solution was added slowly, then the crude product was washed with ice cold water, dissolved in 400 ml of boiling water for recrystallization, filtered and dried at 100°C.

V) Synthesis of 2,3-Diphenyl Quinoxaline:

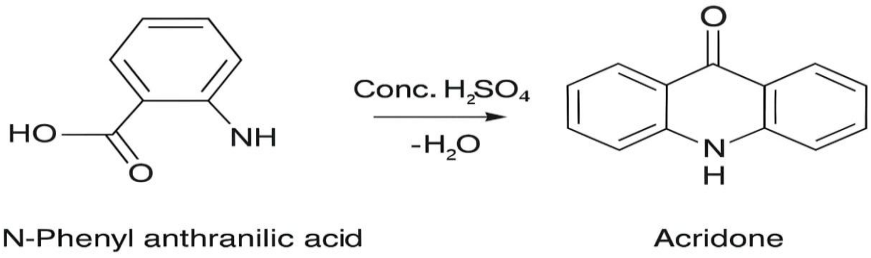


O-Phenylene Diamine **Benzil** **2,3-Diphenyl Quinoxaline**

Conventional Synthesis: Take 1.26gm of benzil was dissolved in 8 ml of warm neutral spirit and transferred into 100 ml round bottomed flask containing 1.08gm of O-Phenylene diamine dissolved in 8 ml of neutral spirit. The mixture was refluxed for 1hr on a boiling water bath. Then, water was added until slight turbidity remains. The crude product was filtered and recrystallised from neutral spirit.

Microwave Synthesis: In 1.26gm of benzil was dissolved in 8 ml of warm neutral spirit and transferred into 100 ml beaker containing 1.08gm of O-Phenylene diamine dissolved in 8 ml of neutral spirit. The beaker was placed in a microwave oven at 250 watts for 4 min. Then water was added until slight turbidity remains. The crude product was filtered and recrystallised from neutral spirit.

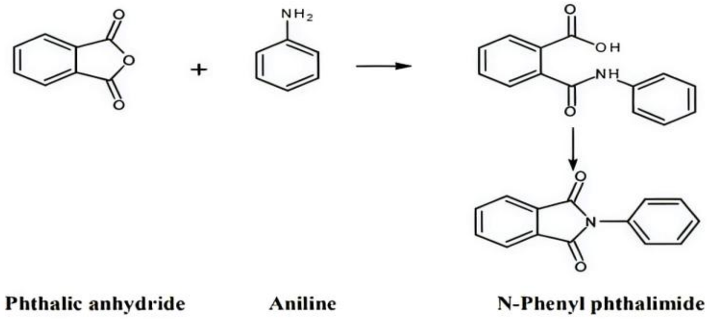
VI) Synthesis of Acridone:



Conventional Synthesis: A mixture of 4gm of N-Phenyl anthranilic acid and 10 ml of concentrated sulphuric acid was taken in a conical flask and heated for 1.5hr on a steam bath. Then the hot dark green solution was poured slowly and continuously into 200 ml of boiling water in 500 ml beaker allowing the acid to run down from the sides of the beaker to prevent spattering. Then the mixture was boiled for 5 min and filtered while hot. The crude product was washed with hot water and recrystallized from acetic acid using charcoal.

Microwave Synthesis: A mixture of 4gm of N-Phenyl anthranilic acid and 10 ml of concentrated sulphuric acid was taken in a conical flask and the reaction mixture was kept in a domestic microwave oven at 250 watts for 4 min. Then the hot dark green solution was poured slowly and continuously into 200 ml of boiling water in 500 ml beaker allowing the acid to run down from the sides of the beaker to prevent spattering. Then the mixture was boiled for 5min and filtered while hot. The crude product was washed with hot water and recrystallized from acetic acid using charcoal.

VII) Synthesis of N-Phenyl Phthalimide:



Conventional Synthesis: A mixture of 1gm of aniline and 1gm of phthalic anhydride was dissolved in 10 ml of glacial acetic acid. The solution was transferred into 100 ml round bottomed flask and refluxed for 1hr. Then, the crude product was separated, filtered and recrystallised from ethanol.

Microwave Synthesis: A mixture of 1 ml of aniline and 1gm of phthalic anhydride was dissolved in 10 ml of glacial acetic acid contained in a 25 ml beaker and placed in a domestic microwave oven at 250 watts for 4min. Then, the crude product was separated, filtered and recrystallised from ethanol.

DRAWBACKS OF MICROWAVE ASSISTED SYNTHESIS: It has been observed that the use of microwaves for synthesis can sometimes cause certain problems.

1. In case of water as solvent its evaporation occurs due to high temperatures apply.
2. Heating reactions above the boiling point of the solvent it increases the pressure which can cause vials to explosion.
3. Some solvents absorb microwaves more readily than others which mean certain solvents are unsuitable.
4. Heat force controlled is difficult and sudden increase in temperature may led to decomposing of molecule.
5. No specific formula for calculating parameters for new synthesis.
6. It cannot heat materials such as sulphur, which are transparent to microwave radiation and installation cost are expensive

APPLICATIONS OF MICROWAVE ASSISTED SYNTHESIS: Microwave-assisted synthesis (MAS) has gained wide importance in modern chemistry and pharmaceutical research due to its efficiency and eco-friendly nature. The following are some important applications of microwave-assisted synthesis in different scientific fields:

1. Drug Synthesis: Microwave-assisted Synthesis (MAS), are environmentally friendly and solvent-free synthesis compared to conventional methods.
2. Organic Reactions: It improved reaction rates, chemical yields and decreased reaction times of various reactions like aldol condensation, oxidation and esterification.
3. Reduced energy consumption microwaves primarily target the sample, resulting in lower energy consumption.
4. Simplified synthetic procedures: The microwave technique operates at elevated temperatures, accelerating the reaction rate.
5. The use of microwave for synthesis of inorganic solid is very efficient technique in m chemistry. It has been used in preparation of ceramics.
6. Application of Microwave in polymer synthesis.

CONCLUSION: Microwave-assisted synthesis (MAS) is a convenient way towards the goal of green chemistry. By using the unique mechanisms of microwave heating, including dipolar polarization and ionic conduction, MAS gives rapid, uniform, and selective energy transfer, resulting in faster reaction rates compared to conventional methods. Comparative studies confirm the advantages of MAS technique include reaction rate acceleration, solvent-free reactions, minimum energy consumption, and no need longer refluxing. By optimizing parameters like temperature, time, and power, MAS ensures higher yields and reproducibility. This is not easily achievable by the other conventional technique. It seems that this innovative technique cannot be easily replaced by other modern methods in the coming years due to its ability to superheat the substrates in an eco-friendly and safe manner with energy-efficient technology for future chemical research and industrial applications.

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