Journal of
Modern Chemistry &
Chemical Technology

ISSN: 2229-6999 (Online)
ISSN: 2321-5208 (Print)
Volume 16, Issue 2, 2025
May–August
DOI (Journal): 10.37591/JoMCCT

https://journals.stmjournals.com/jomcct

Review JoMCCT

Preparation of Organic Compounds by Microwave Technique with Applications

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Abstract

Microwaves are an influential, reliable energy basis that may be adapted to several functions. Recognizing the fundamental technique following for microwaves will supply the chemical researchers with the right equipment and knowledge to be skilled to effectively apply microwave energy to any synthetic path. For chemical reactions and processes, microwaves offer an alternate energy source. Reaction mixtures are heated uniformly without coming into touch with walls using dielectric heating. While preserving respectable percentage yields and selectivity, the reaction time is greatly shortened in comparison to systems that are typically heated (heat). One small disadvantage is that, compared to heating, chemical reactions and processes in the microwave spectrum are more reliant on the tools and materials utilized. Percy Spencer was engaged in a radar-related project in the 1940s. He discovered that the chocolate bar in his pocket melted more quickly than he had anticipated while testing a new vacuum tube. He started pointing the tube at other items, such popcorn and eggs, out of curiosity to see what would happen. After these objects became hot, Spencer realized that microwave energy could have an interesting new application. The microwave oven was soon invented.

Keywords: Microwave, no solvent, purity, organic compound, less pollution

INTRODUCTION

Microwave Technique

It is a modern and fast technology for preparing organic compounds and various chemical reactions in several fields, including the field of organic synthesis. The microwave electromagnetic spectrum region corresponds to the wavelength of (1 cm–1 m) i.e. (30 GHz–300 MHz). The basic principle of its operation is the passage of rays through the walls of the reaction vessel and thus reach the molecules of the mixture, which leads to raising temperatures and these speed up the reaction time to shorten it to minutes and seconds [1, 2]. For this feature and others, the use of this technology has spread widely during the last two decades.

When processing materials that are tough to digest, the microwave digestion system works well for high temperature and pressure requirements. To guarantee incredibly effective safety while in operation, the system combines expert microwave product design, premium raw materials, and creative sensor design. The microwave digesting system has chemical reaction process control and is a microwave accelerated reaction system. The

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Received Date: February 01, 2025
Accepted Date: February 12, 2025
Published Date: February 21, 2025

Citation: Nagham Mahmood Aljamali, Ali Jassim Al-Zuhairi, Shireen Ridha Rasool, Rajaa Abdul Ameerghafil. Preparation of Organic Compounds by Microwave Technique with Applications. Journal of Modern Chemistry & Chemical Technology. 2025; 16(2): 17–25p.

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operation system, display, and control are all integrated [3, 4]. It saves space thanks to its dependable anti-corrosion design throughout the machine. In addition, the device is multipurpose and can be used for a number of microwave chemistry applications, including drying, analytical chemistry, protein degradation, concentration, sample digestion, extraction, organic/inorganic synthesis, and experimental testing of data conditions that mimic chemical processes [5, 6]. Microwaves use electromagnetic radiation with a wavelength of around 12 cm to heat the processes. The radiation is absorbed by the water molecules in each dish. They begin to oscillate (rotational oscillation) to absorb the absorbed microwave energy. However, these oscillations are strongly suppressed by other substances (chemicals) surrounding the water molecules in the meal being heated. As a result of this mechanical interaction (which is similar to the behavior of a mixer in a reaction vessel), the previously absorbed energy is transferred to the meal, with which the microwave radiation does not interact directly, causing it to heat up. The heating of the container is also a secondary effect, since microwave containers do not absorb radiation of such frequencies. The magnetron waves are released from the opposite side of the oven to initiate the electronic device, while the microwave radiation generates a standing wave inside the oven. This implies that while the area near the location of the wave nodes (with zero amplitude density) will be chilly, other areas of the dish, where the standing wave vectors, or the wave's peaks, are located, will be considerably heated. The dishes are either set on spinning stands or another rotating reflector which are utilized to change the oven's intensity distribution and prevent the plates from heating unevenly. Percy Spencer, an American working on radar equipment, made the inadvertent discovery of the phenomenon of microwave interactions with other sorts of interactions, when working with a magnetron, which is also used in commonplace equipment to produce microwaves [7–10].

PREPARATION OF ORGANIC REACTION MODELS USING MICROWAVE TECHNIQUE

The container in which the sample is placed is made of a polymeric material, as this type of material allows microwave waves to penetrate, and waves with a frequency of 245 MHz are used, and the energy is transmitted through the walls of the plastic container. The sample is heated to a temperature below boiling until it melts. It should also be noted that most types of glass, paper utensils, and those made of polyethylene do not absorb microwaves, and therefore the heating process of the reactions placed inside them cannot take place, in addition to the fact that heating the reaction in a plastic container leads to the container melting and damaging it [11–14]. Microwave devices are subject to general safety conditions, and it must be ensured that there is no radiation leakage in them, thus preventing health hazards that may arise from any leakage of radiation waves. Among the general safety instructions is that the microwave oven should not be operated unless the door is completely closed, because exposure to electromagnetic microwaves leads to severe burns (Figure 1).

Figure 1. Microwave device.

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Journal of Modern Chemistry & Chemical Technology
Volume 16, Issue 2
ISSN: 2229-6999 (Online), ISSN: 2321-5208 (Print)

MICROWAVE SPECTROSCOPY

Microwaves are known as one of the types of electromagnetic waves. Electromagnetic waves include: radio waves, ultraviolet rays, gamma rays, etc. They lie between the regions of radio waves and infrared rays. Microwaves have many applications in life, perhaps the most important of which is related to ovens [15]. They are also used to study the rotational spectra of molecules, which must be characterized by the following: The substance must have a dipole moment (permanent polarization moment). The substance must be in the gaseous state, as this leads to a reduction in the interatomic forces between molecules. In the liquid state, we notice the presence of distortion or obstruction of the rotational motion resulting from molecular interference. It can be eliminated by reducing the interatomic forces or eliminating them by measuring the substance in the ideal gaseous state, but this reduces the concentration of the substance in the measurement model [16, 17], which requires the length of the measuring cell must be increased to ensure the largest number of collisions between the incident waves and the particles (Figure 2).

Advantages of Microwave Interactions

The microwave heating technology has several advantages that have made it stand out in recent use due to the speed of the reaction and the short time it takes to prepare the chemical compounds. It is also characterized by a high percentage yield and high purity. The product comes in the form of an impurity-free solid powder. The product is also characterized by being free of environmental pollution and from an economic point of view, it does not consume a lot of solvents. The importance of using the microwave device is in accomplishing many important reactions in terms of application and industry, and the advantages of this technology in terms of reaction speed, purity, and freedom from side products, and its consideration as a means of saving energy and avoiding the user the risk of exposure to hazardous chemicals and preserving the environment from organic and chemical pollutants in general [18–20]. As well as the existence of several different types of microwave devices used in chemical laboratories, their operating principle, the conditions that must be met in the materials to be entered into different chemical reactions, the ideal conditions for using this advanced technology, and its relationship with green chemistry. It belongs to the category of electromagnetic radiation, which is created in nature when an electric current flows through a conductor. Its wavelength is in the range of 30 to 0.3 cm [21, 22]. They are non-ionizing rays and are divided into beams according to their uses. Microwave energy is an unparalleled energy and is radically different from other energies and has many advantages, including: It works inside the material, i.e. it penetrates the surface of the material and interacts with every atom of the material [23–25], i.e. heat is generated inside the material itself.

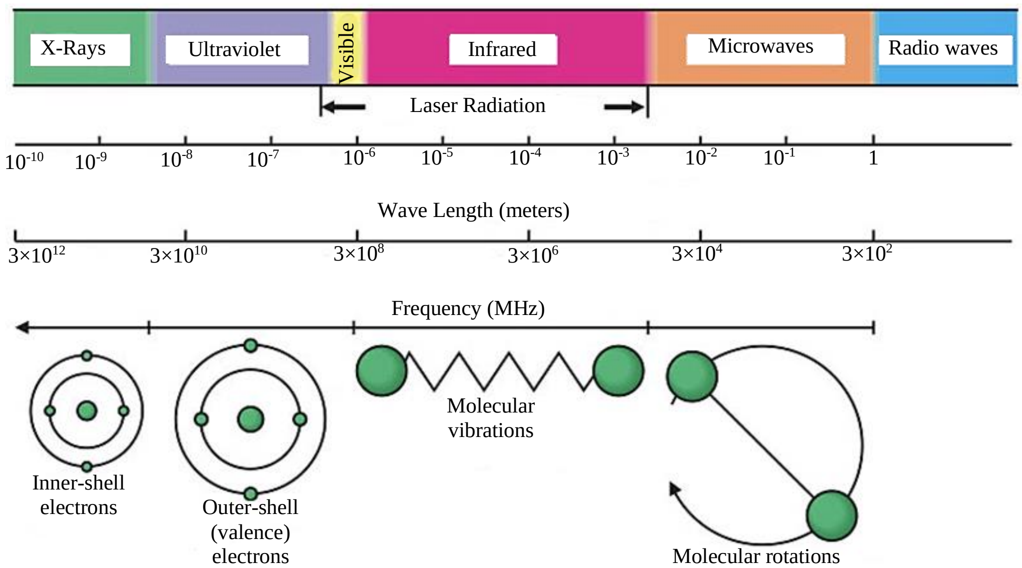

Figure 2. Types of radiations.

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The waves directed at the material are not hot, but rather cold waves, i.e. the amount of heat produced depends primarily on the electrical properties of the material. Reducing the manufacturing time of the material: For example, a material that is manufactured within 24 h using normal energies can be manufactured within 10 min using microwaves, which leads to reducing costs and time. It is characterized by being clean energy as well as its surroundings. It is not an external energy that is directed at the surface of the body and heats it and its surroundings. Rather, it is purely internal energy, as the area surrounding the body remains clean, meaning there is no smoke, dust, or anything that leads to environmental pollution.

The use of microwave energy in the manufacture of materials, especially ceramic materials (materials that helped in the modern scientific renaissance), which require very high heat to manufacture, has led to the production of unparalleled and high-quality ceramic materials [26–29].

Mechanism of Microwave Technology on Organic Reactions

As for the mechanism of heating in a microwave oven, when microwave rays are directed, they are absorbed by the material and work to rotate strongly. The friction created by this spin between nearby molecules raises the temperature. Of course, the rotation speed will affect the rate of heating. The rate of heat generated depends mainly on the percentage of humidity, and the shape, size and mass of the material. An alternate energy source for chemical reactions and their processes is a microwave. Reaction mixtures can be heated uniformly without coming into touch with the walls by using dielectric heating [30]. Figure 3 shows that acceptable percentage yields and selectivity are maintained while the reaction time is greatly shortened when compared to traditionally heated systems (heat).

Microwave technology was first developed just prior to World War II. The food business has been using microwaves since 1970. Laboratory and industrial research started to emerge in the 1980s. In the realm of organic synthesis, the first amine reaction was documented in 1986. Of particular interest is that the first instance of microwave use was in the removal of carcasses. The first source of microwaves was used to heat food, dry it, etc., millions of times. The tools used for these purposes have certain safety standards in order to use them. Electromagnetic radiation, however, is not suitable for conducting chemical reactions according to good laboratory requirements [31–33]. The field in which microwaves are used in chemical laboratories is (microwave-assisted extraction) in the subjects of organic pollutants and isolation and preparation of natural materials. This method has become an alternative to extraction with the traditional tool, which usually requires a long time and large amounts of solvents [34–36]. The high temperature of the extraction solvent brought on by the increased pressure is one benefit of this technique. Also, using a microwave device with short wavelength and high energy rays, a novel Mannich base was prepared from thiobarbiturates and barbiturates [37–39]. The compound gives good effectiveness against fungi, as the reactions were completed in a shorter time (Figure 4).

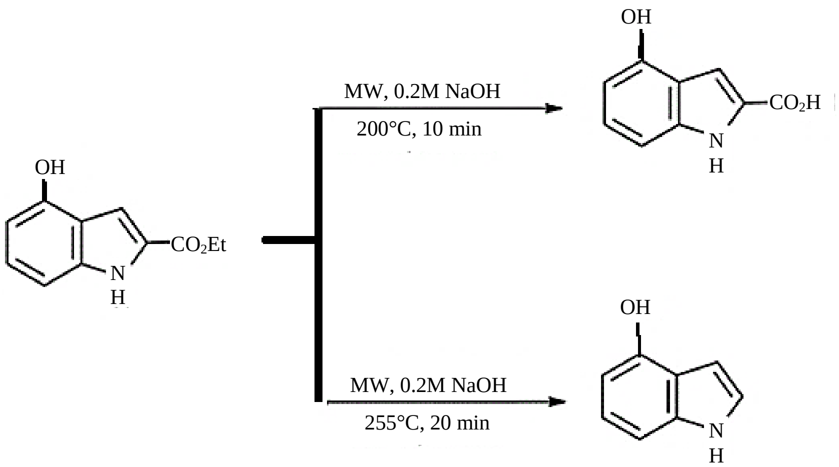

Figure 3. Chemical reaction via microwave in less time.

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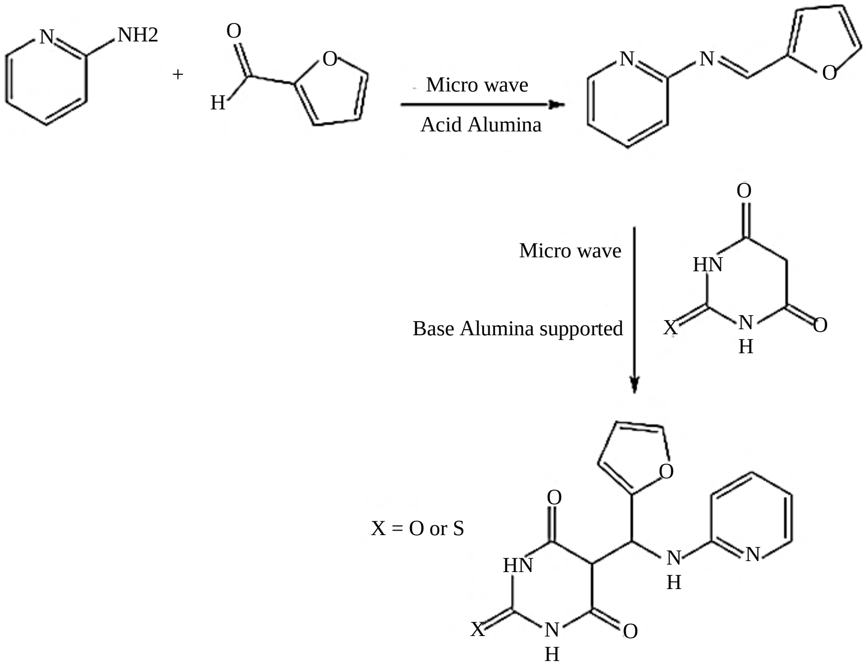

Figure 4. Preparation of antimicrobial compounds by microwave radiation.

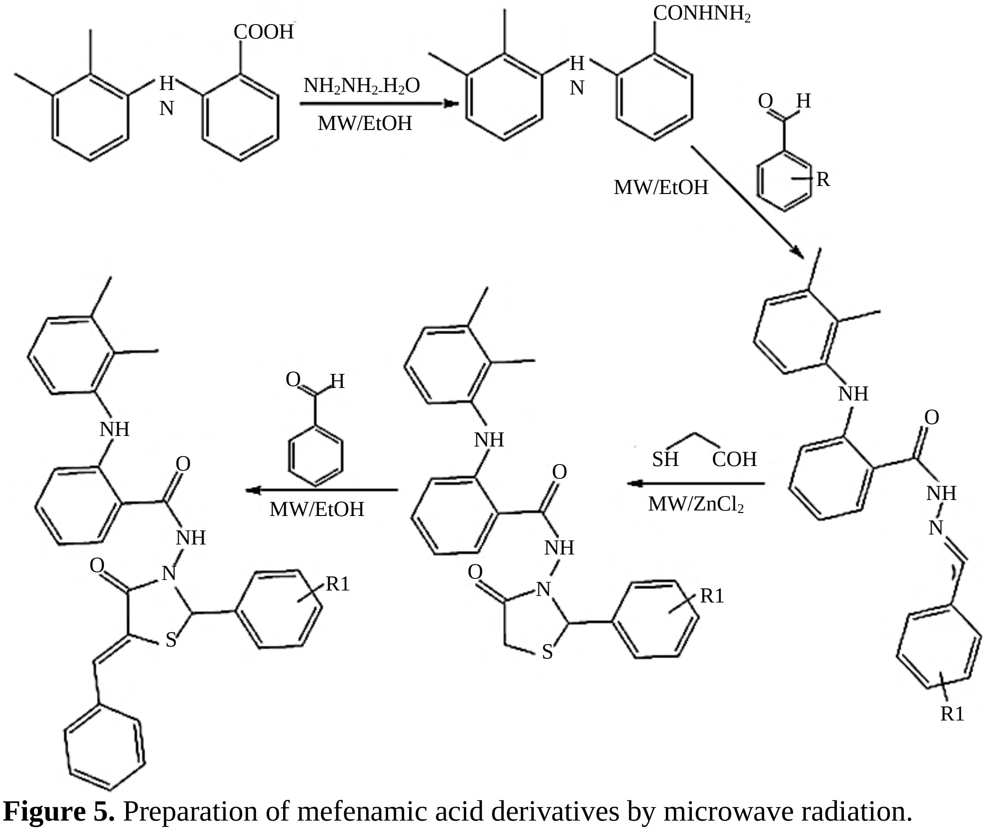

Figure 5. Preparation of mefenamic acid derivatives by microwave radiation.

Many researchers have been able to prepare heterogeneous cyclic compounds using microwaves and microwave technology, which shortened the time and used them as intermediate compounds to prepare many important compounds in life, as they found that they contain vital properties against bacteria, fungi, viruses, oxidation and inflammation. Chalcone compounds are characterized by giving products in good proportions, high stability, ease of purification and being colored [40–43].

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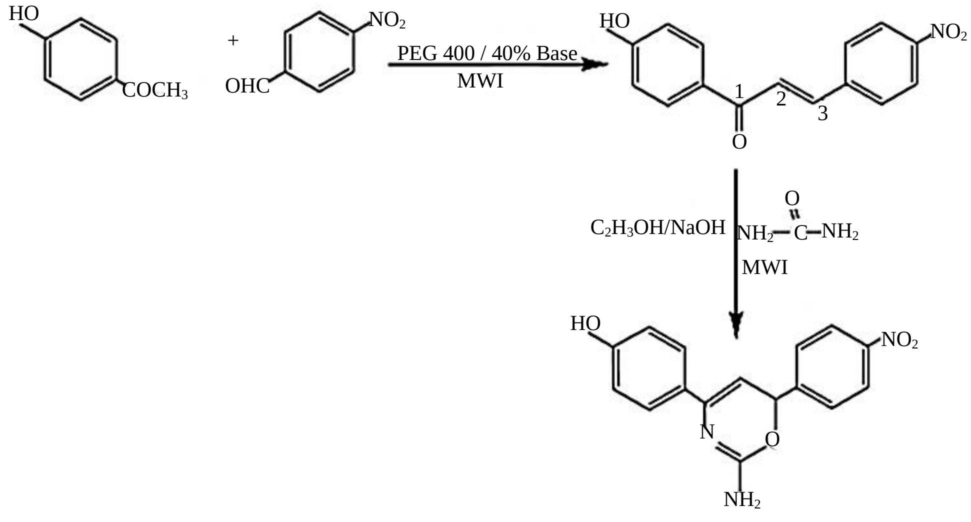

Figure 6. Cyclization of chalcone by microwave radiation.

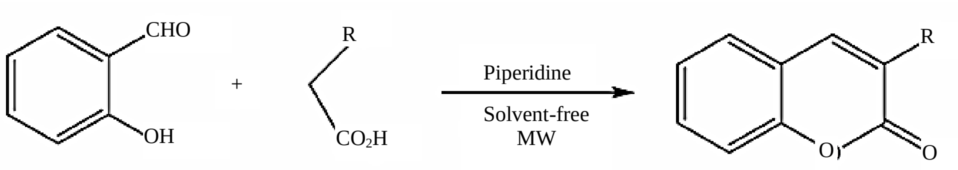

Figure 7. Novengal reaction by microwave radiation.

The researchers used the microwave device to prepare and characterize the chalcone and study its biological activity against bacteria (Antibacterial) and anti-inflammatory (Anti-inflammatory) through sequential reactions that included the formation of new Schiff bases and a compound with a heterogeneous five-membered ring, which is, Thaizolidinone, from Mefenamic acid (Figures 5–7) [44–46].

CONCLUSION

In conclusion, in this survey we have struggled to study how microwave irradiation can be used under green and sustainable restrictions. Also, it involves a high absorption of microwave irradiation through one component of the reaction combination, either the solvent, reagents, or catalyst. Microwaves provide a powerful and efficient energy source for chemical reactions, significantly reducing reaction times while maintaining good yields and selectivity. Their unique heating mechanism offers advantages over conventional methods, though the choice of tools and materials remains crucial. The accidental discovery by Percy Spencer highlights the transformative potential of microwave energy, leading to innovations in both scientific research and everyday applications.

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