Microwave Heating: A Green Synthesis Tool

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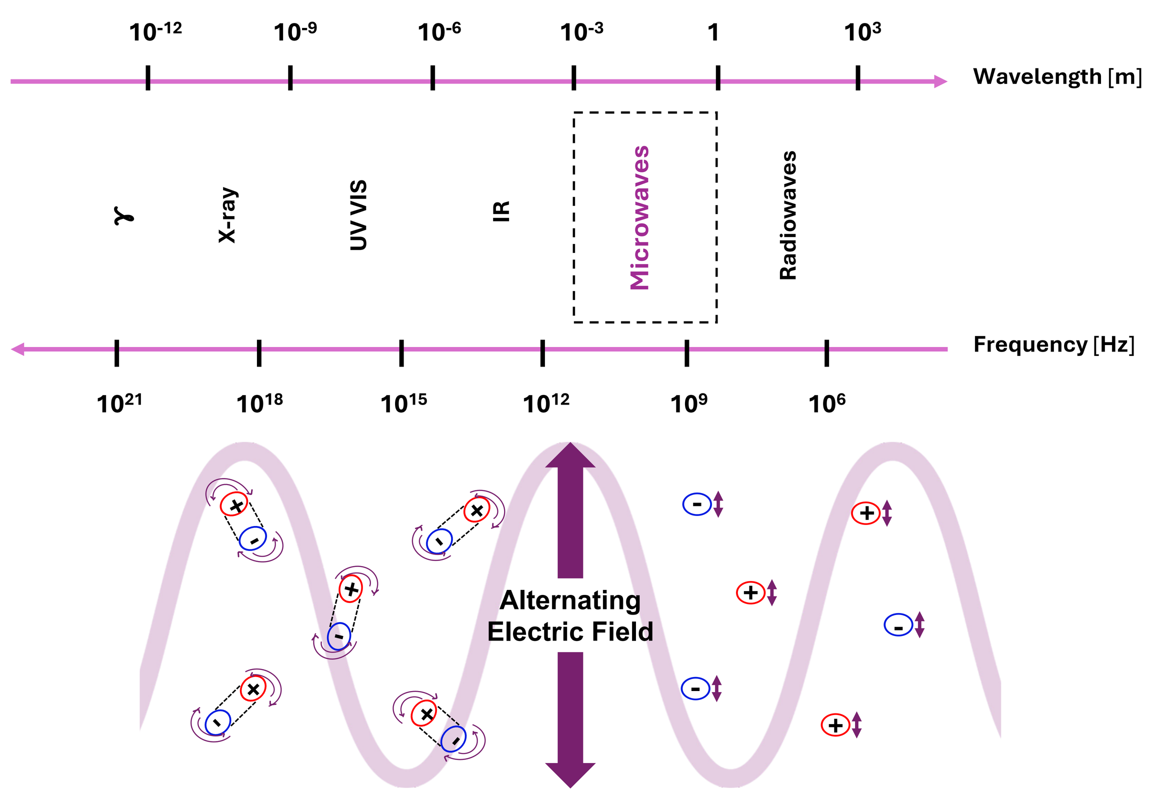
Introduction and History

Microwave irradiation is electromagnetic irradiation in the frequency range of 0.3 GHz to 300 GHz, which corresponds to wavelengths between 1 mm to 1 m.



Dipolar Polarization   Ionic Polarization

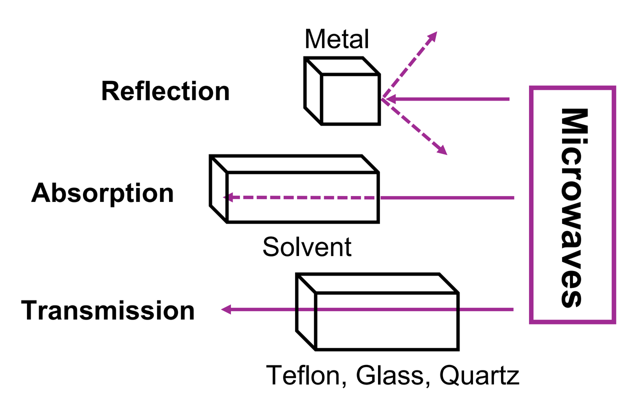
In **1946**, the melting of a chocolate bar in the pocket of Percy Spencer while walking past an open radar waveguide gave him the idea that powerful interactions between microwave radiation and materials (for example, foods) were possible.[1]

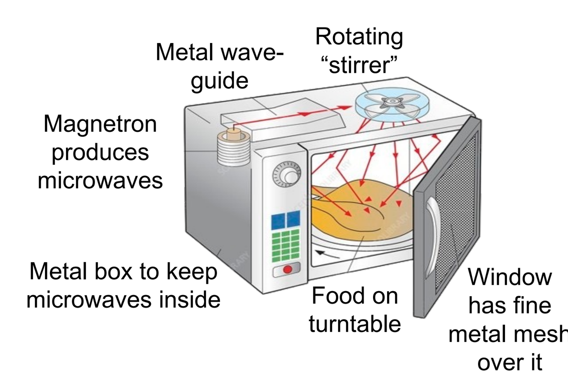
- **1940** The High Power Cavity Magnetron was invented by Henry A. Boot and John T. Randall.
- **1945** The first model of MW oven was built by Percy Spencer at Raytheon.
- **1952** The first patent for a MW oven was issued by Percy Spencer at Raytheon.
- **1955** Tappan marketed the first commercial MW oven for home use.
- **1967** Amana acquired Raytheon and introduced a more affordable Amana Radarange MW oven.
- **1970** In the early 1970s, the US market was dominated by MW manufactured by Amana and Litton.
- **1990** Japanese and Korean manufacturing companies started dominating the US market.
- **1995** The sales of MW oven increased rapidly worldwide.

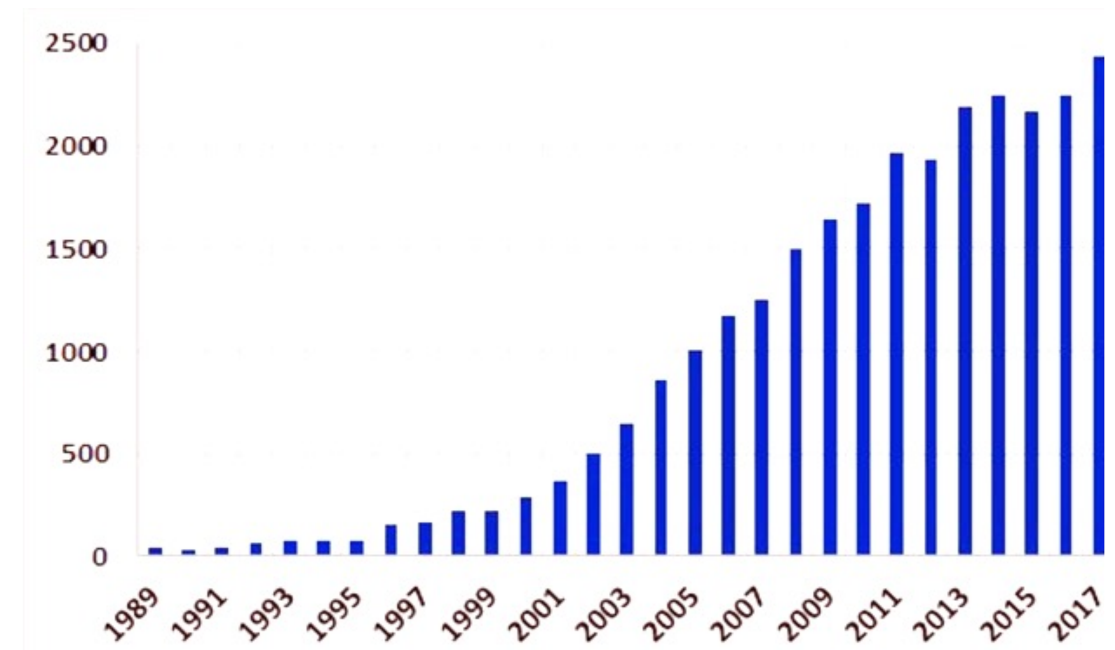
The heating characteristics of a particular material under microwave irradiation conditions depend on a specific substance's ability to convert electromagnetic energy into heat. This ability is determined by the so-called loss tangent, **tan δ**.

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'}$$

ε'' = Efficiency with which electromagnetic radiation is converted into heat.
ε' = Polarizability of molecules in the electric field.







Number of publications related to ***MW*** over the years.

Advantages and Disadvantages

Microwave Heating

Merits

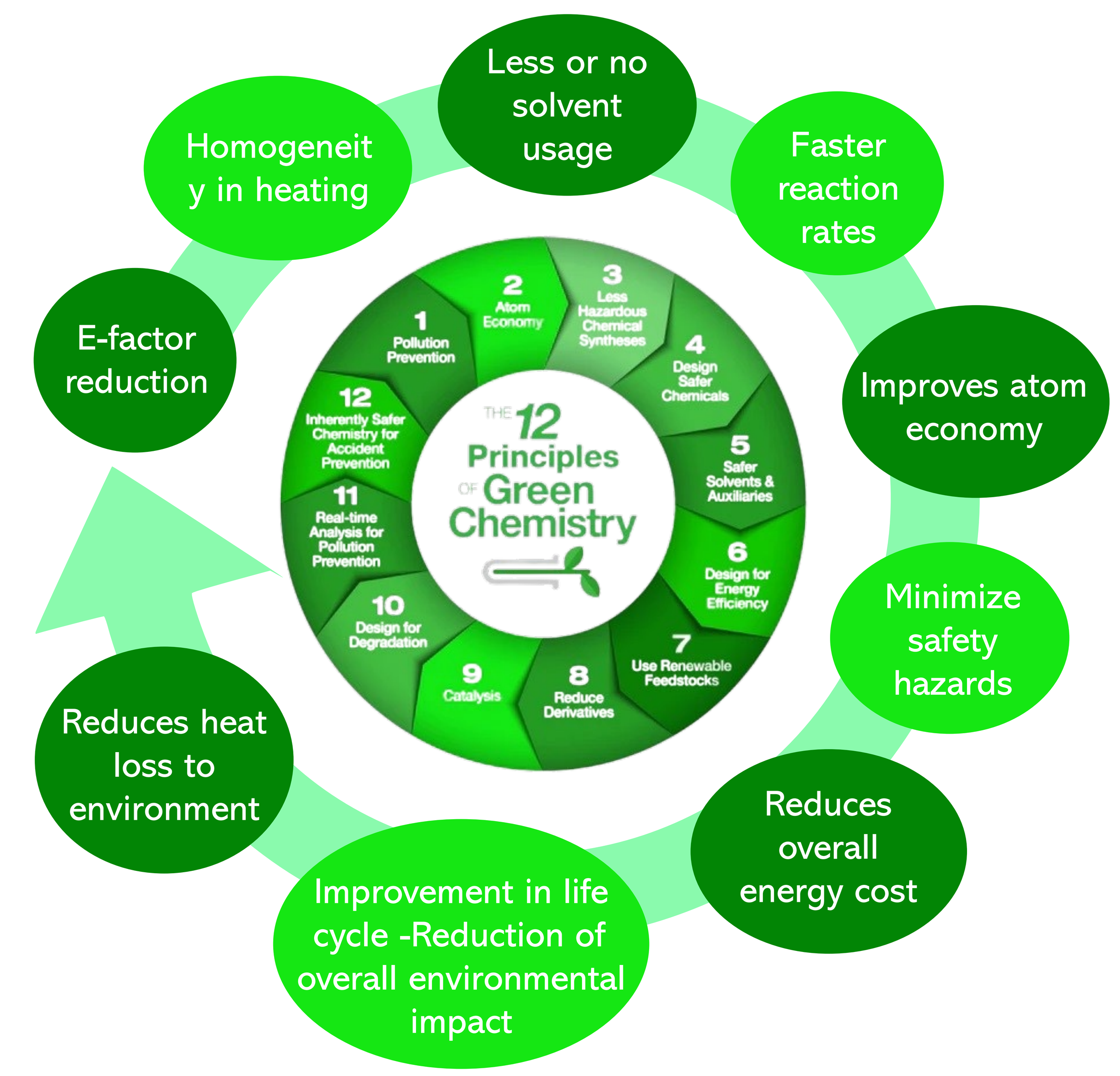
- ***Faster reaction*** — Significantly reduced heating times
- ***Energy- efficiency*** — Direct heating (not vessels) minimizes energy loss
- ***Uniform and selective heating*** — particularly in heterogeneous materials
- ***Better yield and higher purity*** — Less formation of side products and more yield less rigorous purification easier

Demerits

- ***Material specificity*** — Effectiveness varies depending on the material's dielectric properties
- ***Thermal runaway*** — Risk of localized overheating and thermal runaway
- ***Equipment costs*** — More expensive than conventional heating systems
- ***Penetration depth*** — Limited penetration depth can lead to uneven heating in thick materials

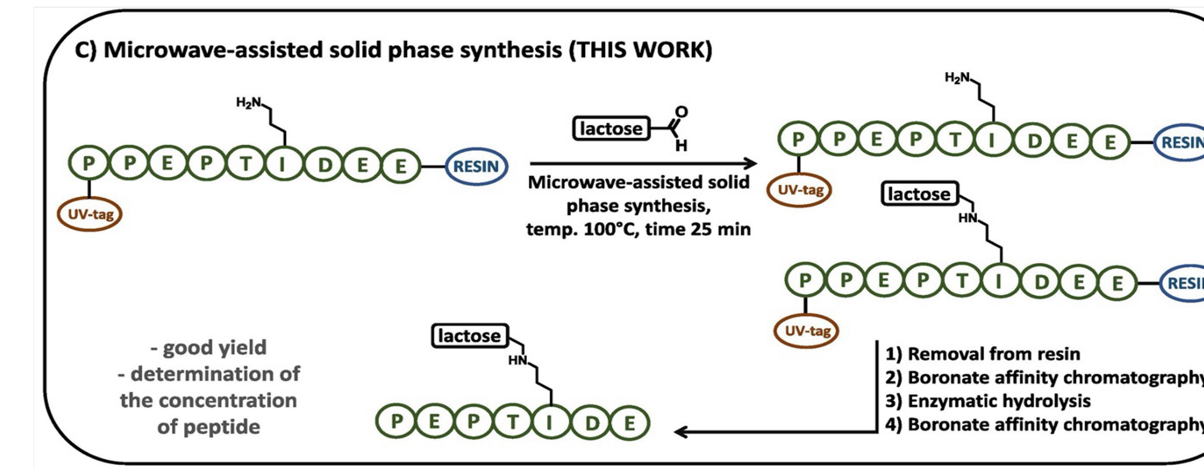
Microwave: Green and Sustainable Chemistry Tool

How does MW relate to Green & Sustainable Chemistry?

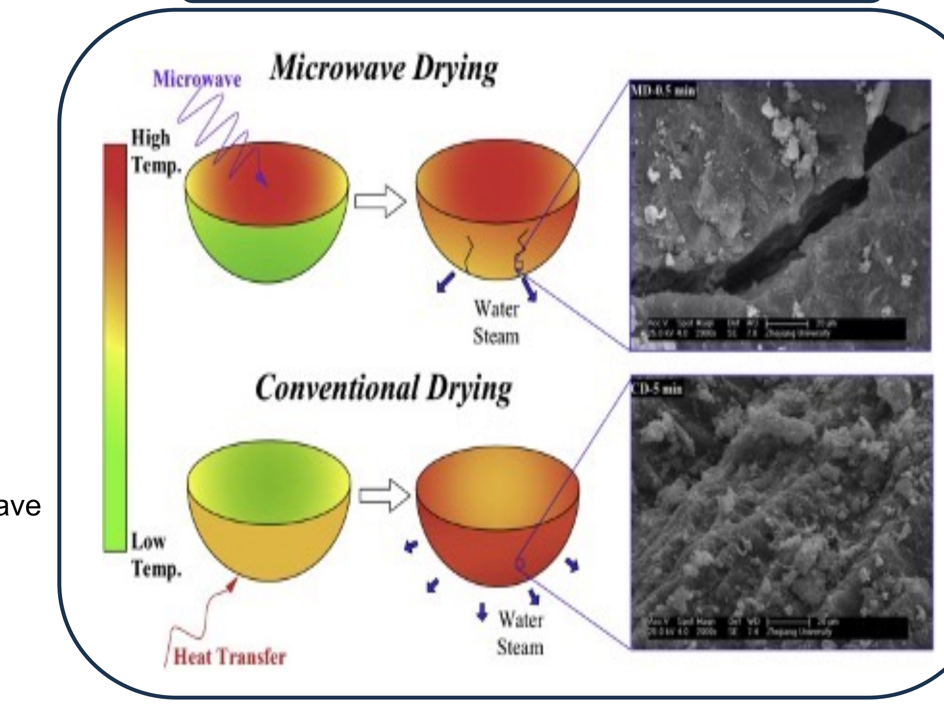


Applications

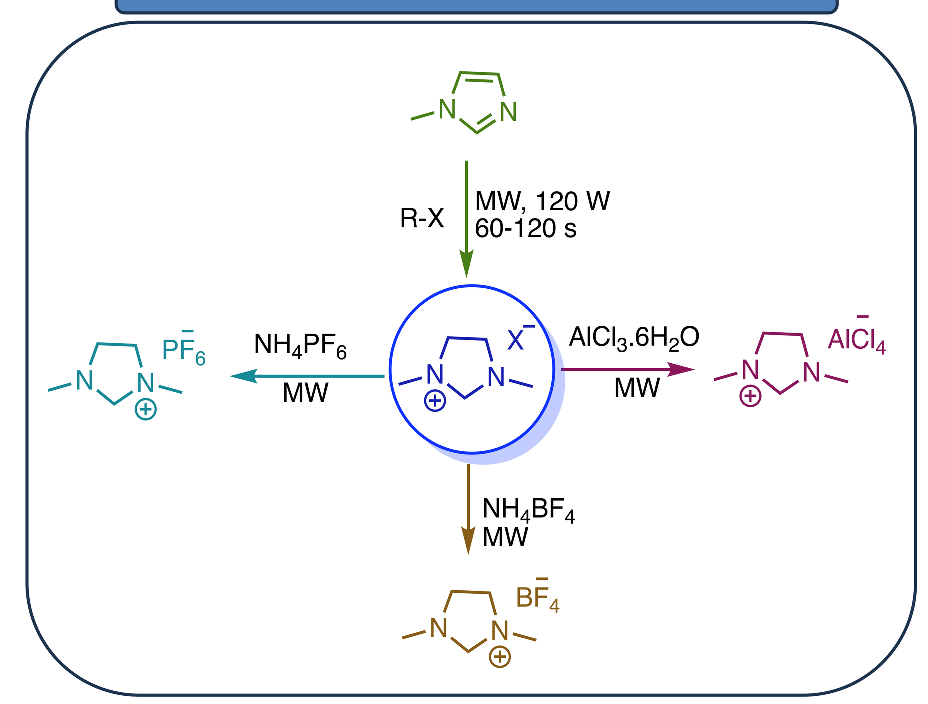
Microwave-assisted peptide synthesis(MAPS)



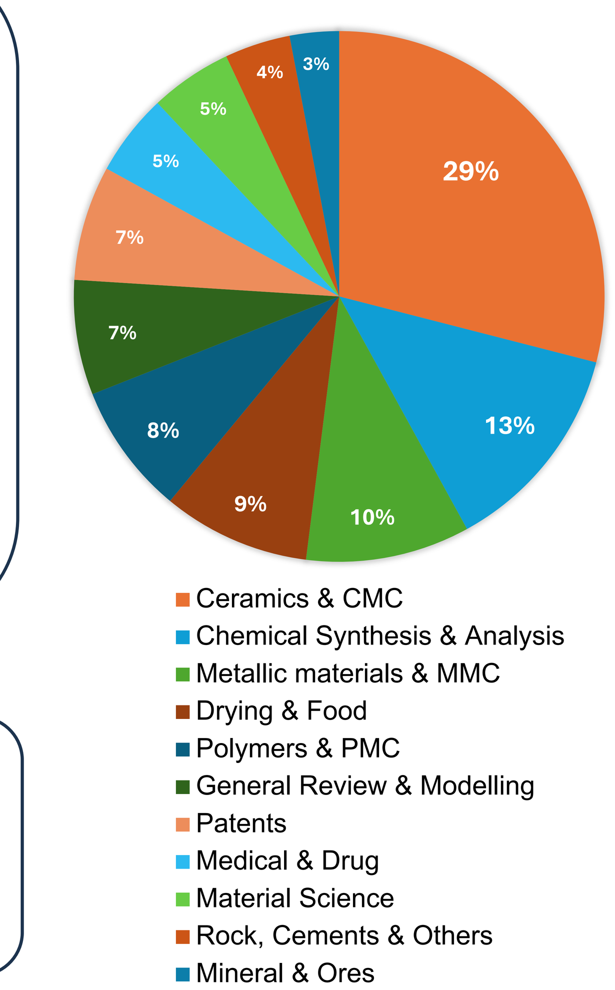
Microwave-assisted drying (MAD)



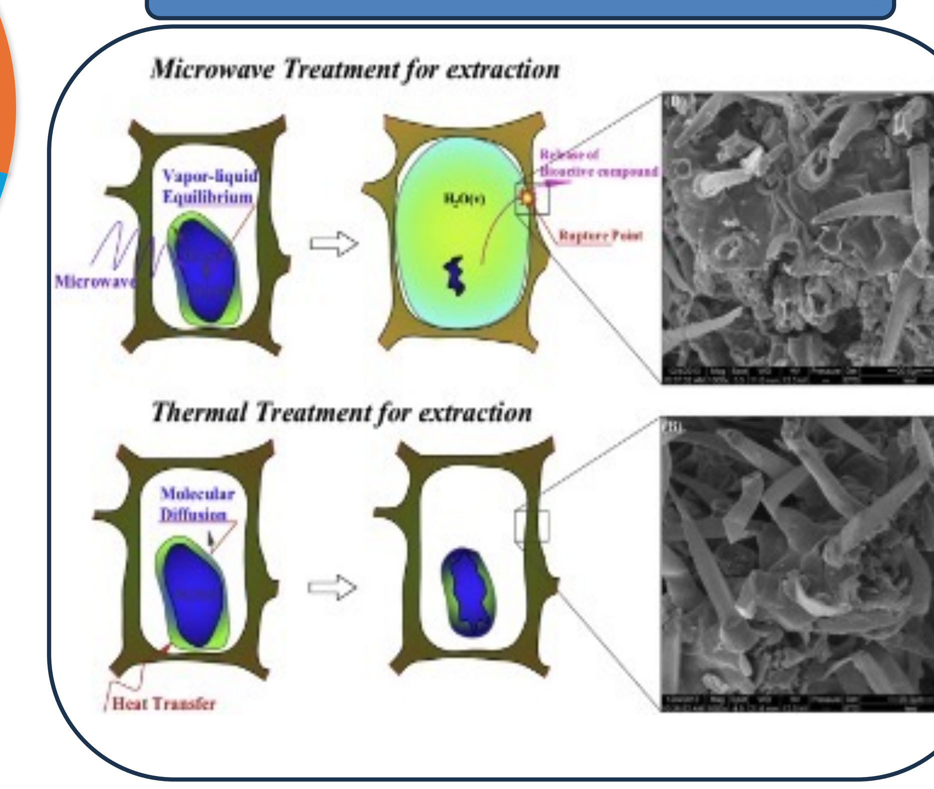
Microwave-assisted synthesis of Ionic Liquids



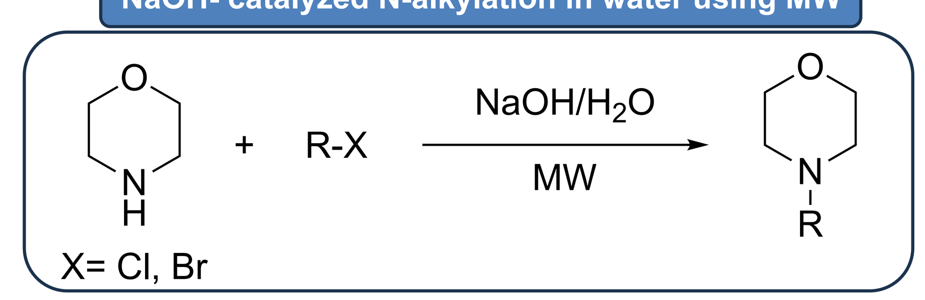
Published research in the field of Microwave processing of material.



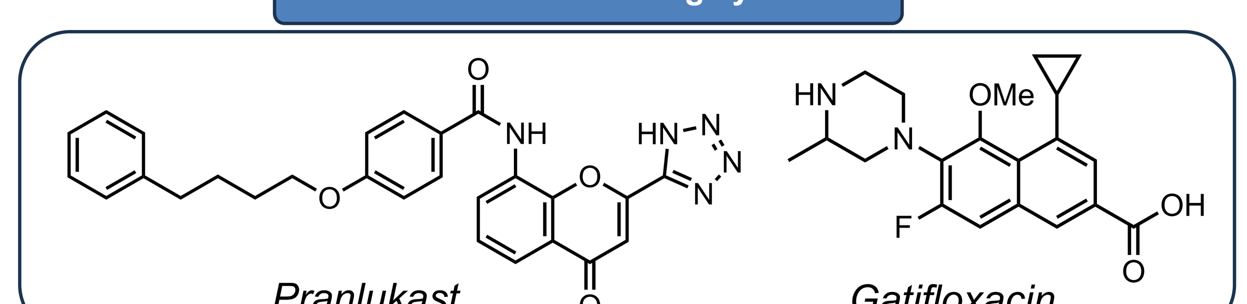
Microwave-assisted extraction (MAE)



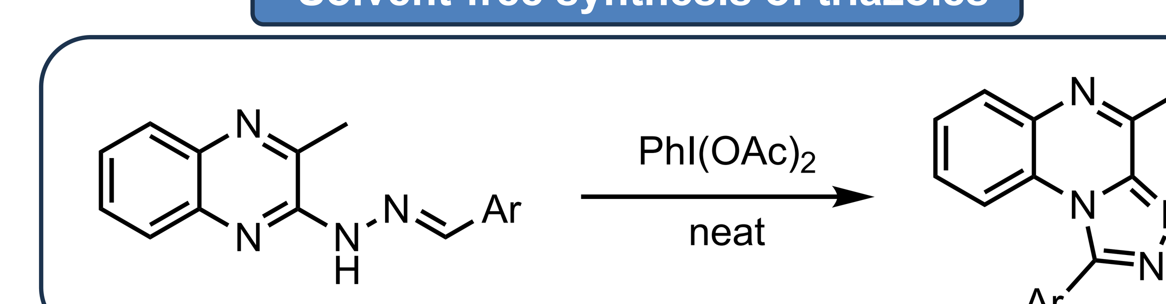
NaOH- catalyzed N-alkylation in water using MW



Microwave-assisted drug synthesis



Solvent-free synthesis of triazoles



Future Perspective

1. Integration with AI to optimize reaction conditions and predict outcomes
2. Enhanced equipment design
3. Process optimization and modeling
4. Integration with conventional methods
5. Applications across various fields including pharmaceuticals, polymers and catalysis
6. Advanced materials synthesis such as nanoparticles and functional materials

References

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Acknowledgments

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