Microwave-Assisted Extraction

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Introduction to Dielectric Heating

Microwave and substance reaction

Microwave (MW) irradiation uses an electromagnetic field at a specific frequency. The MW frequency range is an ample interval that ranges from 300 MHz to 300 GHz. However, only a few frequencies are allowed for industrial, scientific, and medical uses (ISM frequencies), and in general 0.915 and 2.45 GHz are those most used worldwide.

A typical MW generator for such frequencies can be found in the magnetron, the same device that equips domestic and laboratory MW ovens. Magnetrons for industrial applications can reach power ratings in the tens of kilowatts (kW); laboratory appliances usually use ratings below 1 kW. Recently, the introduction of solid-state generators has permitted the emission band of the MW generator to be made narrower, allowing the user to vary the frequency of the system within the range of allowed ISM frequencies.

At a frequency of a few gigahertz (GHz), namely, at the allowed ISM frequency of 2.45 GHz, matter interacts with the electromagnetic field mainly via dipole reorientation and induced polarization phenomena. Even though the interaction with the electric field is of principal importance for most of the chemical environment, the fact that the magnetic component accounts for the magnetic loss in compounds with high permeability is another mechanism via which heat is generated. At 2.45 GHz, the energy of an MW photon is close to 0.00001 eV, and hence it is too weak to break even hydrogen bonds. Moreover, it is also much lower than the energy required for Brownian motion. Thus, one has to keep in mind that the efficiency of MW irradiation on chemical syntheses is strictly related to the conversion of electromagnetic energy to heat. Both the nature of reactants and the geometry of the MW reactor affect heat generation in the reaction medium.

Properties of microwave exposed materials

The major physical parameters that are of importance for MW-assisted extraction include solubility, the dielectric constant, and dissipation factors. Working at 2,45 MHz, the polarity of the solvent is the main factor because solvents with high dielectric constants (e.g., water and alcohols) can absorb more MW energy than nonpolar solvents

Mechanism of Microwave Extraction

The fundamentals of the microwave extraction (MAE) process are different from those of conventional methods (solid-liquid or simply extraction) because the extraction occurs as the result of changes in the cell structure caused by electromagnetic waves.

In MAE, the process acceleration and high extraction yield may be the result of a synergistic combination of two transport phenomena: heat and mass gradients working in the same direction. On the other hand, in conventional extractions, the mass transfer occurs from inside to the outside, although the heat transfer occurs from the outside to the inside of the substrate (Fig. 1). In addition, although in conventional extraction the heat is transferred from the heating medium to the interior of the sample, in MAE the heat is dissipated volumetrically inside the irradiated medium. The solvent penetrates into the solid matrix by diffusion (effective), and the solute is dissolved until reaching a concentration limited by the characteristics of the solid. The solution containing the solute diffuses to the surface by effective diffusion. Finally, by natural or forced convection, the solution is transferred from the surface to the bulk solution (Fig. 2).

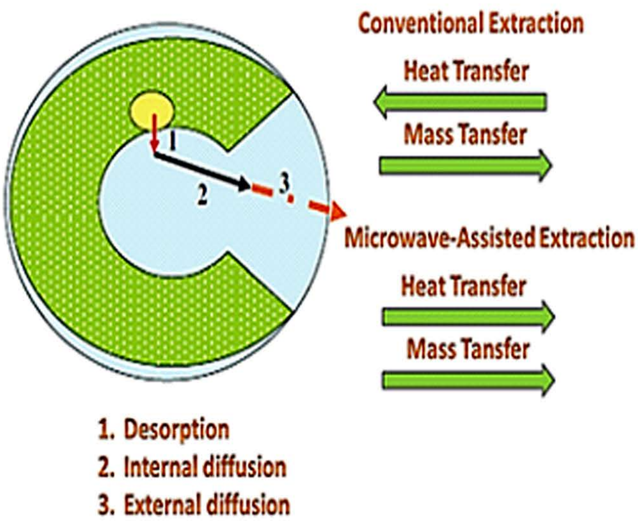

Figure 1

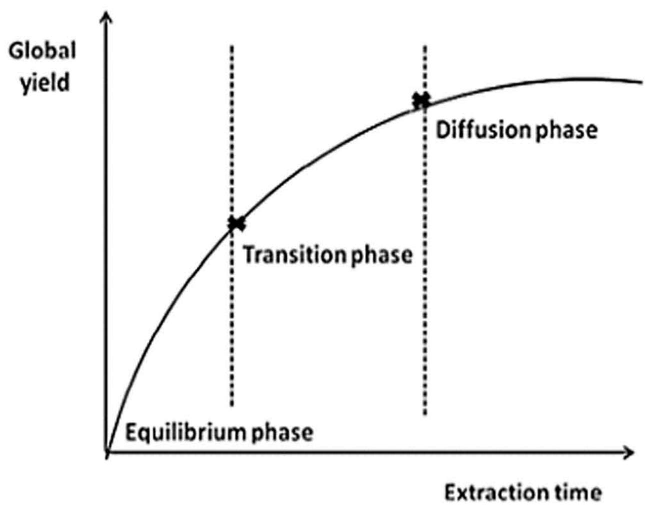

Figure 2

The extraction process takes place in three different steps: an equilibrium phase where the phenomena of solubilization and partition intervene, in which the substrate is removed from the outer surface of the particle at an approximately constant velocity. Then, this stage is followed by an intermediary transition phase to diffusion. The resistance to mass transfer begins to appear in the solid-liquid interface; in this period the mass transfer by convection an diffusion prevails. In the last phase, the solut must overcome the interactions that bind it t the matrix and diffuse into the extracting sol vent. The extraction rate in this period is low characterized by the removal of the extrac through the diffusion mechanism. This point i an irreversible step of the extraction process; i is often regarded as the limiting step of the pro cess.

Extraction of Essential Oils by distillation

The traditional way of isolating volatile compounds as essential oils from plant material is distillation. During distillation, fragrant plants are exposed to boiling water or steam, releasing their essential oils through evaporation. Recovery of the essential oil is facilitated by distillation of two immiscible liquids (water and essential oil) based on the principle that the combined vapor pressure equals the ambient pressure at the boiling temperature. Thus, the ingredients of essential oil, for which boiling points normally range from 200خC to 300خC, are evaporated at a temperature close to that of water. The laden steam of the essential oil rises and enters narrow tubing that is cooled by an outside source. As steam and essential oil vapors are condensed, both are collected and separated in a vessel traditionally called the Florentine flask. The essential oil, which is lighter than water, floats at the top while water goes to the bottom and can easily be separated. The amount of essential oil produced depends on four main criteria: the length of distillation time, the temperature, the operating pressure, and, most importantly, the type and quality of the plant material. Typically, the yield of essential oils from plants is between 0.005% and 10%

Microwave Hydrodistillation (MWHD)

The process microwave hydrodistillation (M-WHD), which was developed by Stashenko et al. in 2004, is based completely on the classical hydro distillation principle; a part of the hydrodistillation assembly line is placed in the microwave oven (Fig. 3).

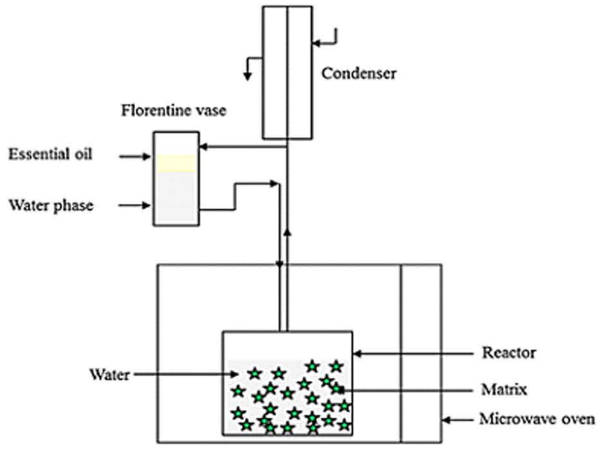

Figure 3

The matrix is installed with water into a reactor that has already
been placed inside the microwave oven. The refrigeration system and the part estimated to recover essences are situated outside the oven.

interval:	بازه گسترده
dipole reorientation:	جهت‌گیری مجدد دوقطبی
induced polarization:	پلاریزاسیون القایی
permeability:	نفوذپذیری
strictly:	موکداً، صرفاً
conversion:	تبدیل، تغییر
solubility:	انحلال‌پذیری، قابلیت حل
dissipation:	اتلاف
dissipated:	منتشر شدن، پراکنده شدن
convection:	انتقال گرما
substrate:	لایه
intermediary:	میانجی
exposed:	در معرض قرار گرفتن
laden:	مملو