§10. Elucidation of the Microwave Special Effects in Water

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The role of water as a solvent in microwave-assisted organic syntheses has risen dramatically because of the interest in ecofriendly processes germane to Green Chemistry. As a heating source, microwave radiation has become one of the most attractive heating methods in chemical syntheses, contrary to conventional heating methods which provide heat externally through conduction and convection at the interface between the reactor walls and the heat bath (e.g. an oil bath). Microwave heating typically occurs in the bulk of a reaction sample through penetration of the microwaves. The microwave method presents several advantages over conventional methods in driving chemical reactions thermally: e.g. shorter reaction times, uniform temperature distribution, energy saving, and high product yields. In the present study we report the heating behavior together with the heating mechanisms of aqueous electrolyte solutions by the two components of microwave radiation – namely, the electric field (***E***-field) and the magnetic field (***H***-field) – using a semiconductor microwave generator and a single-mode resonance applicator. It is important to recognize that the microwave's ***E***-field and ***H***-field cannot be divorced completely from one another.

Experimental Setup: The microwave irradiation setup with the single-mode cavity TE_{103} (transverse electric 103 mode), used to irradiate the reactor contents, a short plunger, an iris, a three-stub tuner, a power monitor and an isolator. The continuous microwave radiation was generated from a 2.45-GHz microwave semiconductor generator (Fuji Electronic Industrial Co. Ltd.; GNU-201AA; maximal power, 200 W). The resonance of the microwaves was adjusted with the iris and the plunger at 1.5 cycles. Heating of the sample solution (1.0 mL) was achieved by positioning the quartz tube (diameter: 5.0 mm; internal diameter: 4.0 mm) in the single-mode microwave apparatus of either at positions of maximal electric field density or at the maximal magnetic field density (***H***-field; position **(ii)**) within the waveguide.

Result and discussion: The influence of *E*-field and *H*-field heating was examined using ultrapure water sample whose density changed in the presence of the NaCl electrolytes. Under *E*-field irradiation, the heating rate improved remarkably when NaCl was added compared to ultrapure water (**Figure 1**), reaching a maximum at ca. 0.50 M in NaCl. By contrast, under H-field irradiation the heating rate showed a remarkable increase when NaCl was added to the ultrapure water sample. Generally, heating of water does not occur under the microwaves' magnetic field component. However, that heating of water/electrolyte solutions is enhanced considerably. Moreover, the heating rates increased on increasing the quantity of NaCl. Clearly, the heating behavior of the aqueous electrolyte solutions under H-field conditions is remarkably different from E-field irradiation with 2.45-GHz microwaves. In this regard, the heating mechanisms pertaining to the electric field and the magnetic field are discussed later.

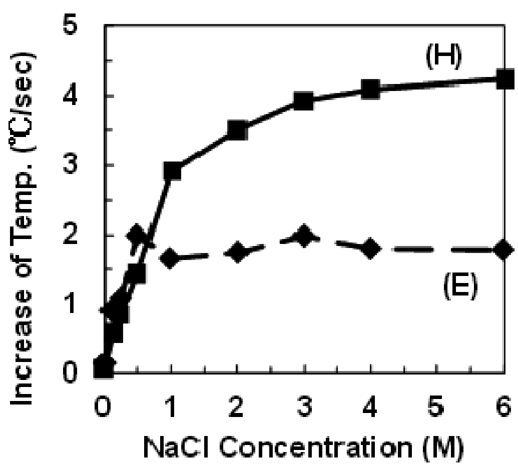

Fig. 1 - Temperature increase rate of aqueous NaCl solution under microwave irradiation