MICROWAVE ENHANCEMENT OF EVAPORATION OF A POLAR LIQUID. I.
Experimentation

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The evaporation of a polar liquid at low pressure and exposed to microwave radiation has been investigated, as an example of an endothermic reaction. A fixed, high column of liquid was irradiated in a waveguide with 2.45 MHz-CW microwave radiation. The temperatures of the gas and the liquid in contact with the interface and the evaporation rate were measured as functions of the non-equilibrium gas pressure and the microwave field.

Empirical equations relating the dynamic non-equilibrium parameters to each other are given. The results show that microwave heating offers the possibility or reversing a temperature difference between the two phases at a gas-liquid interface. Other special features of the action of microwaves are discussed.

Among the many industrial applications of microwave power is its use in the areas of drying, freeze-drying and defrosting. All these examples fall into the class of endothermic processes, changes which require energy for their occurrence. The use of microwaves is an elegant solution, because they can rapidly supply much energy, inside any dielectric material.

In the classical method of carrying out these processes, heat is conducted to the interface by thermal contact with one or both phases. Theoretical approaches deal mainly with the problems of mass and heat transfers, but few articles treat what happens at the interface and how to describe, at least numerically, the mechanism of the reaction itself. The need for such information is especially manifest when microwaves are used to accelerating a process.

Whether microwave irradiation exerts an influence only via thermal action or whether there are field-specific interactions is now a fundamental question we must answer. According to the laws of thermodynamics, the microwave electric field might introduce an external parameter at the interface and could modify the equilibrium or the rate of the reaction.

It is the purpose of the present two papers to investigate these problems by studying the evaporation of a polar liquid, the surface of which is exposed to a known microwave field intensity.
Parameter inventory for describing the interfacial reaction rate

It is well known that the observed evaporation rate of a liquid into vacuum differs significantly from that indicated by the Hertz–Knudsen equation, which is derived from the classical kinetic theory of gases

$$J_K = \alpha \frac{P_s(T_{cp}) - P_c}{\sqrt{2\pi MRT_{cp}}}$$

(1)

where $P_s(T_{cp})$ is the saturated vapour pressure at the absolute temperature $T_{cp}$, and $P_c$ is the pressure at which the experiment occurs. In this publication, the constraint parameters are denoted by the subscript $c$. The introduction of the coefficient $\alpha$, described by Knudsen as the "evaporation coefficient", to obtain better agreement with experiment is questionable [1–3]. The relation proposed by Hickman [4],

$$J_H = \frac{1}{\sqrt{2\pi MRT}} \left( \frac{P_s(T_i)}{\sqrt{T_i}} - \frac{P_c}{\sqrt{T_{cp}}} \right)$$

(2)

to take into account the value of the temperature of the interface, $T_i$ (which differs from the temperature $T_{cp}$), also fails in many cases. Erikson [5] found it convenient to correlate his data with the expression

$$J_E = -k \log \frac{P_c}{P_s(T_{cp})}$$

(3)

which introduces the ratio of the pressures as a measure of the deviation of the chemical potential from its equilibrium value.

A more general approach has been proposed by Bertrand et al. [6, 7] and Mokhlisse [8]. They have found that the temperature of the liquid in contact with the evaporating surface is never that of the bulk, but lower. Following the usual methods of analysing irreversible processes, they describe the relationship between heat and mass transfers. The rate of evaporation is then the direct sum of two independent terms:

$$J_M = -A \log \frac{P_c}{P_s(T_i)} + B \left( \frac{1}{T_g} - \frac{1}{T_l} \right)$$

(4)

or

$$J_M = A' \left( \frac{1}{T_{cp}} - \frac{1}{T_l} \right) + B' \left( \frac{1}{T_{cp}} - \frac{1}{T_g} \right)$$

(4')

in which the differences in temperature between the two phases ($T_l$ for the liquid temperature at the interface, $T_g$ for the vapour temperature at the interface) and the external temperature $T_c$ are introduced separately to specify how far the stationary state is from the equilibrium.

This point of view was supported by the direct observation of the temperature differences evoked in this treatment. With water and ethyl alcohol the evaporating liquid first coexists in equilibrium at some specified temperature $T_c$. The pressure