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EVAPORATION OF BUBBLE AEROSOL DROPLETS FROM SOLID SUBSTRATES

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Evaporation-kinetic studies have been made on droplets formed under equilibrium and nonequilibrium conditions. There are differences due to the physicochemical features.

Charged droplets are formed when gas bubbles break at the surface of an aqueous electrolyte solution [1], and their compositions differ from that of the solution [2]. This is of interest to the theory of atmospheric processes [3] and also for optimizing heat and mass transfer in industry [4]. Here particular interest attaches to how small drops evaporate from solid substrates.

We used drops formed under nonequilibrium and equilibrium conditions; in the first case, the drops were made by bubble breaking at the surface, which involves highly nonequilibrium conditions, and the droplet formation speeds may be 10-100 m/sec [5]. When a bubble breaks, a cavity remains in the liquid, from which a column is ejected that breaks up into droplets. The bubbles were produced from a single capillary in distilled water, which was 2.2 cm below the surface. The generation rate was 23-25 bubbles a minute. At 50 mm from the surface there was a PTFE plate, which had been cleaned by boiling in freshly prepared chromic acid followed by repeated washing in double-distilled water and boiling in it. In the second, an MSh-10 microsyringe (scale 0.2 μl) was used in depositing a drop of distilled water slowly on the PTFE, the volume being the same. We compared results for identical-volume drops made under the two conditions. There were 40 such comparisons. The drops were selected and their parameters were measured in a saturated atmosphere in both cases. The height and base diameter were determined with an MIR-2 microscope (scale division 0.07 mm).

Table 1 gives the polynomials fitted to the volume V and side surface S in terms of the time τ; the polynomials have been fitted to minimum variance. The assumption was that the drops were spherical, which was checked from the criterion [6] $R_{ef} << a$, in which a is the capillary constant. The variations in volume and surface for the bubble aerosol were

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TABLE 1. Formulas Fitted to Droplet Evaporation from PTFE (0.1 M NaCl, 25°C, 755 mm Hg, capillary diameter 1.6 mm)

Polynomial	Variance	Notes
$V = 4{,}48 \cdot 10^{-4} - 5{,}28 \cdot 10^{-5}\tau + 3{,}38 \cdot 10^{-6}\tau^2 - 1{,}22 \cdot 10^{-7}\tau^3$	$3{,}48 \cdot 10^7$	Bubble aerosol
$S = 1{,}88 \cdot 10^{-2} - 2{,}74 \cdot 10^{-3}\tau + 2{,}23 \cdot 10^{-4}\tau^2 - 7{,}67 \cdot 10^{-6}\tau^3$	$3{,}42 \cdot 10^6$	The same
$V = 5{,}17 \cdot 10^{-4} - 4{,}46 \cdot 10^{-5}\tau + 9{,}69 \cdot 10^{-7}\tau^2$	$2{,}41 \cdot 10^5$	Bulk liquid
$S = 2{,}10 \cdot 10^{-2} - 1{,}51 \cdot 10^{-3}\tau - 1{,}10 \cdot 10^{-4}\tau^2 + 1{,}52 \times 10^{-5}\tau^3 - 4{,}19\tau^4$	$2{,}93 \cdot 10^5$	The same

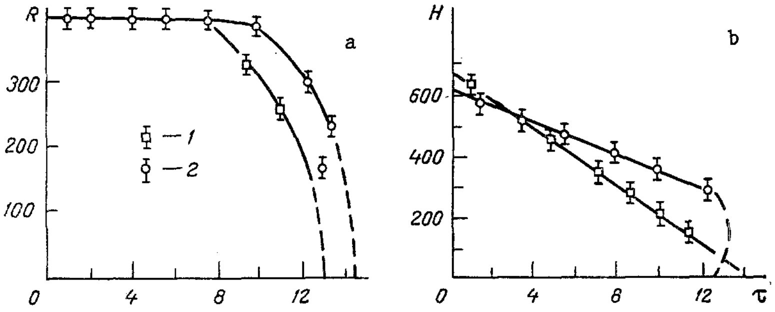

Fig. 1. Radius at base of drop R (a) and height H (b) as functions of time τ: 1) bubble aerosol; 2) bulk phase; τ in min and R and H in μm.

different from those for the bulk phase. The evaporation details were derived from the variation in the height H and base radius R. Figure 1 shows these. We used drops with identical parameters at $\tau = 0$ (20 comparisons). The bulk-liquid drop lifetimes always exceeded those for the bubble aerosol ones. Up to time τ^*, the wetting perimeter was maintained (only H decreased), but for $\tau > \tau^*$, H and R both decreased. The $R(\tau)$ with constant R for $\tau < \tau^*$ is due to wetting hysteresis on the hydrophobic surface. As the substrate becomes more hydrophilic, τ^* decreases for both. For the bulk liquid, τ^* was larger than for the aerosol, so droplets evaporate more rapidly from a hydrophilic substrate. The increased rate for the bubble aerosol is due to the charge [7], since a charged drop has lower surface tension [8]. The surface tension is reduced because there is less molecular interaction in the surface layer, which reduces the work needed to transfer a molecule from the liquid to the gas.

NOTATION

V, drop volume; S, side surface area; R_{ef}, effective radius; R, base radius on solid surface; H, height; τ, time.

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