Optical Determination of the Size of Fast-Growing Water Droplets in an Expansion Cloud Chamber

Water droplet growth by condensation at low constant supersaturations can be computed theoretically (1, 2). This process occurs in the atmosphere and can be investigated in thermal diffusion cloud chambers. The growth is determined mainly by vapor diffusion and takes several seconds.

The processes during a fast increase of supersaturation have not been clarified sufficiently. In experiments (3, 4), considerable droplet growth has been observed during periods of the order of 10 msec.

The present paper reports the measurement of the sizes of fast-growing water droplets as function of time at heterogeneous and homogeneous condensation.

The condensation is facilitated by adiabatic sub-

\[
\theta = 15^\circ
\]

\[
\theta = 45^\circ
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Fig. 1. Theoretical intensity function \( i_\lambda \) vs size parameter \( \alpha = 2\pi r/\lambda \) (\( r \) = sphere radius, \( \lambda \) = light wave length) at a refractive index \( n = 1.333 \) and different fixed scattering angles \( \theta \).
pressure expansion of vapor-saturated air in a Constant-
temperature-expansion-chamber; the expansion ratio
可以 be varied over a wide range. For better repro-
ducibility the measuring process was automated. A
detailed description will be published later.

For observation, the droplets are illuminated by a
5 mW Helium–Neon-laser which produces linearly
polarized light of wavelength 632.8 nm. The intensity
of the light scattered by the droplets can be measured
as a function of time at any angle between $\theta = 15^\circ$ and

$\theta = 165^\circ$. For the measurement, an EMI 9698 QB
photomultiplier is used. The angular aperture of the
light-measuring device is limited to $2^\circ$ by stops. The
results are displayed on a storage oscilloscope.

The scattering of light by spheres is described by the
Mie theory. The scattering intensities at certain obser-
vation angles have been calculated and are available
from several published tables, e.g., (5). The theoretical
intensity function at a constant observation angle and
at an increasing sphere radius proves to be highly
structured (see Fig. 1). Periodically occurring pointed
peaks can be assigned to uniquely determined sphere
sizes. Besides, a more distinct fine structure can be ob-
served at an increasing sphere radius. For a complete
representation of the curve, especially for larger values
of $a$, function values in smaller intervals than available
from the tables would be required, but for this work a
linear interpolation was used.

Several measurements at different expansion ratios
were made. The experimental intensity vs time func-
tions for two different observation angles at heterogen-
eous condensation and an expansion ratio of 1.19
are shown in Fig. 2. Comparing them with the theoreti-
cal curves shows a surprisingly high similarity. Hence
the condensing aerosol must be monodispersed. If the
width of the distribution function were not very small,
at least the fine structure of the measured curves would
be unobservable.

At an expansion ratio between 1.43 and 1.45 the
onset of the homogeneous condensation can be ob-
served. The corresponding relative humidity between
465 and 495% is in agreement with the theoretical value
of critical supersaturation (6). The experimental in-
tensity vs time functions at an expansion ratio of 1.50
(Fig. 3) prove that also for homogeneous conden-
sation the droplets grow approximately monodisper-
sed. If the expansion ratio exceeds 1.70, the patterns of
the theoretical intensity functions are not present in the

Fig. 2. Experimental light scattering intensity
(relative units) vs droplet growth time at het-
terogeneous condensation, an expansion ratio $\beta = 1.19$ and
different fixed scattering angles $\theta$ (top, $15^\circ$; bottom, $45^\circ$).

Fig. 3. Experimental light scattering intensity (rela-
tive units) vs droplet growth time at homogeneous
condensation, an expansion ratio $\beta = 1.50$ and a
scattering angle $\theta = 15^\circ$.

measured curves any more. This could be explained by very high droplet concentration (multiple scattering) and/or polydispersity of the droplets (continuous new formation).

The intensity vs time functions yield by comparison with the Mie intensity functions the absolute droplet growth at different expansion ratios (Fig. 4). For a discussion of the observed droplet radius vs time functions and a comparison with existing theories, the pressure vs time functions must be taken into account. Results of investigations concerning the time development of pressure in the expansion chamber will be included in a further paper.

ACKNOWLEDGMENTS

The author expresses his thanks to Prof. Dr. O. Preining for many helpful discussions. A portion of this work was supported by the National Air Pollution Control Administration, Consumer Protection and Environmental Health Services, U.S. Public Health Services, Grant Number 5 R01 AP 00468-06. The storage oscilloscope was placed at our disposal by the Fonds zur Förderung der wissenschaftlichen Forschung, Wien, Austria, Antrag Nr. 1307.

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Received February 8, 1973; accepted February 15, 1973