Further Remarks on Ice Multiplication in Clouds

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The results of Auer et al. (1969) and Burrows and Robertson (1969) which are described above agree very well with my original observations (Hobbs, 1969) that the ratio of ice particles to ice nuclei in clouds decreases with decreasing temperature. The fact that similar results have now been obtained in a number of different locations is encouraging. The observations made by Burrows and Robertson are particularly interesting in that their method for deducing the concentrations of ice nuclei was quite different from that used by myself or Auer et al. It would appear, therefore, that the observed decrease in the ratio of ice particles to ice nuclei with decreasing temperature is not simply due to instrumental errors in measuring ice nuclei.

Finally, I would like to repeat the statement made in the last paragraph of my paper; namely, "that a comparatively high cloud top temperature is probably not a sufficient condition for a high ratio of ice particles to ice nuclei." The important task which lies ahead is to determine both the necessary and sufficient conditions for a high ratio of ice particles to ice nuclei in clouds.

REFERENCES


Comments on "A Generalized Equation for the Solution Effect in Droplet Growth"

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Low (1969) has discussed the importance of using the practical osmotic coefficient \( \phi \) or the mean ionic activity coefficient \( \gamma \) for determining the surface vapor pressure of droplets at various solution concentrations. He derives Eq. (10) which describes the vapor pressure lowering due to the curvature and solute effects. He then proceeds to show that, for sufficiently dilute solutions, this equation reduces to Eq. (13). It should be noted that Low's Eq. (10) is identical to the equation (2.50) derived by Byers (1965), and Low's Eq. (13) is identical to the equations (2.8a) derived by Mason (1957) and (3.42) by Fletcher (1962), if we substitute the relation \( \nu \phi = \nu i \) in Low's equations.

In the midst of his brief summary of the derivation of the droplet vapor pressure equations, Low presents a table which lists the values of the van't Hoff factor \( \nu i \) for various electrolytes which he obtained from Eq. (8). One naturally assumes that the tabulated values are equivalent to the van't Hoff factor \( \nu i \) used in Fletcher's, Mason's and Byers' droplet vapor pressure equations, and are presented so that one can use these values in place of \( \nu \phi \). However, Low's values are not equal to \( \nu \phi \) and cannot therefore be used directly in either Low's Eqs. (10) and (13) or Mason's, Fletcher's and Byers' equations. Low's \( \nu i \) values are based on a modification to Raoult's law, but as pointed out by Byers when dealing with electrolytes, it is a frequent practice in physical chemistry to work in terms of osmotic pressure and not with a modification to Raoult's law for ideal solutions. On this basis one obtains an exact equation for \( \nu \phi \) [see e.g., Robinson and Stokes, 1955, Eq. (2.16); Low, 1969, Eq. (7)], i.e.,

\[
\nu \phi = -55.51 (\ln \alpha)/m.
\]

Values of \( \nu \phi \) (or \( \nu i \)), computed from this equation and listed in Table 1, can be used in Low's Eqs. (10) and (13) as well as Byers', Mason's and Fletcher's droplet vapor pressure equations. Low's values serve no apparent purpose and only mislead the reader into assuming that his values can be applied to the droplet vapor pressure equations. Coincidentally, Low's Eq. (8) is a series approximation to the above equation. Therefore, Low's \( \nu i \) values approach those in Table 1 as a approaches unity or as the particle becomes sufficiently dilute.

It should be pointed out that application of the dilute