with a particular orientation to the eye, but for convenience we regard them as having a definite location. The 22° halo, generally seen as a circle normal to the line from the sun to the eye, if seen in hoar frost soon after sunrise is so obviously on the ground that we say it is a horizontal hyperbola. Similarly the rainbow, when seen as a dewbow on ponds covered with an oily film, on cobwebs, or on delicate new-sown grass, becomes an ellipse. In general, halo phenomena are regarded as projected on the celestial sphere. A little consideration makes it clear that a horizontal circle through the sun, as it is progressively raised on the side away from the sun, becomes steadily smaller and finally disappears when its inclination to the horizontal is equal to the zenith distance of the sun.

Although the number of observations is too small to allow definite conclusions, it is of interest to note that the four well-developed horizontal circles that I have observed have all been in small cirro-stratus sheets far below the ordinary cirrus level, at some 5,000 ft. or less; of trace observations, one has been at low level in ice-crystal fog, three at high level, and three at doubtful heights. The brief life and sudden appearance and disappearance of Mr. Cave's display suggest a low level, and consequent high angular velocity, of the cloud.

The occurrence of these arcs in cloud believed to have originated from condensation trails is of interest to me because such trails sometimes seem to yield no arcs, which suggests that they may be made up of very small crystals, complex crystals, or sub-cooled droplets. Of nine sets of trails seen, five did not approach the sun, three yielded no arcs, and one yielded a brilliant circumzenithal arc. The aircraft that formed the latter trail was estimated to be flying at 3,000 ft. and a thin ice-crystal haze was present at the same general level, since a faint circumzenithal arc was present below small patches of alto-cumulus. It may be significant that the two possible orientations of crystals forming this arc (vertical axis of symmetry, and horizontal axis of symmetry with two side faces horizontal) are two of the possible orientations of crystals forming the horizontal circle (vertical axis of symmetry, horizontal axis with two side faces horizontal, horizontal axis with two side faces vertical, and horizontal axis with side faces randomly oriented). Perhaps readers in Britain, where condensation trails must have been only too common in the last five years, can give more information on optical effects in this type of cloud.

D. B. O. SAVILE.

Division of Botany and Plant Pathology,
Central Experimental Farm,
Ottawa.

---

[1] *Nature*, **154**, 240 (1944).

THE letter of Dr. Savile and private correspondence I have had with Dr. Paul White convinces me that I must have been mistaken, and that what I saw on May 2 was a small part of the parhelic circle.

No doubt 'tilted' is a better word to use in connexion with halo phenomena than 'vertical'; but the latter term has been in use for a long time and did not originate from me.

C. J. P. CAVE.

Stoner Hill,
Petersfield.

Cryoscopy of Solutions

A. V. Brancker, S. J. Leach and V. A. Daniels suggest[1] that θ, the depression of the freezing point of a solvent by a solute of m molal concentration, can be given by $\theta = Km^b$, where K is the cryoscopic constant and b a constant very nearly unity.

Such a relation, admittedly empirical, is fundamentally of an incorrect form because it cannot lead to the necessary thermodynamic requirement that θ/m is finite when $m = 0$, and furthermore, K so defined is a cryoscopic constant at unit molality, a quantity smaller than the limiting or van't Hoff value. The ability of this relation to accommodate data over a wide range of concentration from 0 to 1 molal is apparent only. This agreement exists because $d\theta/dm$ and θ/m, although identical at $m = 0$, diverge very slowly with increasing concentration, and b is the ratio of these quantities.

It can be shown thermodynamically, for solutions obeying Raoult's law, that $m = \alpha\theta + \beta\theta^2 + \gamma\theta^3 + \ldots$, where α is the reciprocal of the van't Hoff constant, β and γ are functions of heat of fusion and its temperature coefficient. From this it follows that b is given by $d \log \theta / d \log m = (\alpha + \beta\theta + \gamma\theta^2)/(\alpha + 2\beta\theta + 3\gamma\theta^2)$, a function rather insensitive to variation in θ because of the relative magnitudes of α, β and γ. This small variation is illustrated well by ideal benzene solutions, for which $m = 0{\cdot}1953\theta + 2{\cdot}4 \times 10^{-3}\theta^2 + 1{\cdot}4 \times 10^{-5}\theta^3$. This leads to values of b varying from 1 to 0·945 for concentrations from 0 to 1 molal respectively. Non-ideal solutions can be represented in a similar form with different coefficients and slightly smaller values of b. Such variations in slope would be barely noticeable in a logarithmic plot of the empirical relation, and most certainly tend to be masked by experimental variation in θ.

There remains to discuss the experimentally observed decrease in θ/m with increasing concentration. Many of the reported anomalies in the literature can doubtless be attributed to the use of the van't Hoff limiting constant at finite concentrations. Rigid calculation shows that, for ideal benzene solutions, we must expect θ/m to change from 5·122 at $m = 0$ to 4·81 at $m = 1{\cdot}0$ molal. The effect of applying the limiting constant to ideal solutions of a substance of formula weight 100 would be to give an apparent value of 107·5 at 1 molal. For non-ideal solutions such variations will be even larger.

The data given for solutions of tetralin in benzene[1] show anomalies which are too large to be so explained.

1. Low concentrations give θ/m already in excess of the accepted limiting value 5·122, a value expected from thermal data and corroborated by the careful and extensive measurements of Bury and Jenkins[2] on the freezing points of numerous benzene solutions.
2. The molecular weight of tetralin found is 136 instead of 132·2 which its formula requires.

These abnormalities are removed if one assumes that insufficient precaution was taken to prevent access of moisture to the benzene during the measurement. Assuming these solutions to be saturated with water (0·0335 per cent at 5·4° C.)[3], then approximately the observed depressions are too high by 0·120° C. Making this correction gives the values θ/m in column 4 (below). Excluding the value at the lowest concentration, which appears to be in error, θ/m now shows a variation with concentration which is quite close to the values calculated for an ideal solution and shown in column 5.

The data extrapolate to $\theta/m = 5{\cdot}1$. Assuming