Pressure Coefficient of Surface Tension and the Expansion Ratio of High Pressure Cloud Chambers*

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IN operating an argon-filled cloud chamber at 110 atmospheres Johnson, De Benedetti, and Shutt[1] found that good tracks were formed with an expansion ratio of 1.04, whereas with the same gas and vapor in a chamber at 1.5 atmospheres tracks were formed with an expansion ratio of 1.07. In both instances the vapor was a 50–50 mixture of water and n-propyl alcohol.

A reduction of the expansion ratio with increasing pressure can probably best be understood as an effect of the gas pressure on the surface tension of the droplets. According to the Kelvin theory[2] of charged droplets, the vapor density δ_r in equilibrium with a droplet of radius r is given by the equation

$$\delta_r = \delta_\infty \exp\left[(M/R\theta\rho)(2T/r - e^2/8\pi k r^4)\right], \quad (1)$$

where δ_∞ is the vapor density in equilibrium with a flat surface of the liquid, M is the molecular weight of the liquid, R is the gas constant, θ is the absolute temperature, ρ is the density of the liquid droplet, T is the surface tension, e is the electric charge on the droplet, and k is the dielectric constant of the surrounding gas. Before the expansion, when the temperature is θ_1 and the vapor density is $\delta_\infty(\theta_1)$, ion droplets grow to a radius r_1 where $\delta r_1(\theta_1)$ is equal to $\delta_\infty(\theta_1)$, i.e., $r_1 = (e^2/16\pi k T)^{\frac{1}{3}}$. An adiabatic expansion of the chamber to a volume $(1+\epsilon)$ of the original volume reduces the vapor density to $\delta_\infty(\theta_1)/(1+\epsilon)$ and the temperature to

$$\theta_2 = \theta_1(1+\epsilon)^{1-\gamma}, \quad (2)$$

and the droplet at its lower temperature grows until it is again in equilibrium with the surrounding vapor, a condition expressed by the equation

$$\delta r_2(\theta_2) = \delta_\infty(\theta_1)/(1+\epsilon). \quad (3)$$

Here it is assumed that the time is long enough for the droplet to come into temperature equilibrium with the gas, but so short that no change other than that produced directly by the expansion occurs in the ambient vapor density. The radius of a droplet in equilibrium with the new conditions is found by solving Eq. (1) with the value of δ_r given by (3), and $\delta_\infty(\theta_2)$ equal to the vapor density in equilibrium with a flat surface at the temperature θ_2 of the expanded gas. Here it is convenient to represent the ratio of the saturated vapor densities at the two temperatures by the usual form of equation

$$\ln\left[\delta_\infty(\theta_1)/\delta_\infty(\theta_2)\right] = a(1/\theta_2 - 1/\theta_1),$$

and the resulting condition on r_2 may be written

$$2T/r_2 - e^2/8\pi k r_2^4 = (R\rho/M)[a(1-\theta_2/\theta_1) - \theta_2 \ln (1+\epsilon)]. \quad (4)$$

If the value of r_2, thus determined, exceeds $r_{max} = e^2/4\pi kT$ at which δ_r in Eq. (1) has its maximum value, then the droplet can grow indefinitely and reach a visible size. With this value of r_2 inserted in (4) and expressing the

temperatures in terms of the expansion ratio by (2), we find as the condition for the growth of large drops,

$$(1+\epsilon)^{1-\gamma}(a+\theta_1 \ln (1+\epsilon)) = a - (3M/R\rho)(\pi k T^4/2e^2)^{\frac{1}{3}}. \quad (5)$$

The constant a for water has the value 5330, that for n-propyl alcohol is 5700, and the constant for the mixture may be assumed to be about 5500. Consequently, the term in θ_1 is negligible, and ϵ is determined by

$$(1+\epsilon)^{1-\gamma} = 1 - (3M/R\rho a)(\pi k T^4/2e^2)^{\frac{1}{3}}. \quad (6)$$

With $M = 39$ for the mixture, $\rho = 0.9$, $\gamma = 1.66$, and $k = 1$, Eq. (6) gives values for T of 18.2 and 27.2 dynes per cm corresponding to the observed values 1.04 and 1.07 of $1+\epsilon$ at pressures of 110 and 1.5 atmospheres, respectively. The surface tension of n-propyl alcohol is given in the International Critical Tables as 23.8 at normal pressure and 20° C, but no data are given for this liquid when under high inert gas pressures. However, a lowering of surface tension by gas pressure of this order was found for ether and alcohol in atmospheres of air and hydrogen by Kundt.[3]

The understanding of this effect may lead to a better selection of gas and vapor for high pressure cloud chambers.

[1] T. H. Johnson, S. De Benedetti, and R. P. Shutt, Rev. Sci. Inst. **14**, 265 (1943).
[2] Das Gupta and Ghosh, Rev. Mod. Phys. **18**, 225 (1946).
[3] A. Kundt, Ann. d. Physik **12**, 538 (1881).

Anomalous Values of Certain of the Fine Structure Lines in the Ammonia Microwave Spectrum

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RECENT measurements[1] have demonstrated that the fine structure lines in the ammonia microwave spectrum show certain anomalies. The lines arising from transitions between levels where $K = 3$ are definitely displaced from the positions predicted for them by the empirical formula which has been constructed to fit the remainder of the lines. The lines arising when transitions occur between levels where $K = 3$ and where J is an odd integer are displaced to the long wave-length side of the positions, while those due to transitions between levels where $K = 3$ and where J is an even integer are displaced to the short wave-length side.

Qualitatively, the origin of this effect may readily be understood. It is well known that rotation levels where $K \neq 0$ are doubly degenerate. When $K \neq 0$, but is not a multiple of 3, these doubly degenerate levels belong to the mixed symmetry type[2] $\gamma\delta$ and they cannot be split apart by any perturbation possessing a threefold symmetry, that is, by any perturbation whose origin lies within the ammonia