# Droplet growth in vapor under irradiation

P. Selyshchev

*Department of Physics, University of Pretoria, Private bag X20 Hatfield 0028 South Africa*
selyshchev@gmail.com

The theoretical approach is developed for change of drops in the atmosphere of own steams and buffer gas under irradiation. It is shown that a radiation influences on the area of existence and size of stable drop. Under irradiation the change of drop becomes more complex: the unmonotonous and periodical change of size of drop becomes possible.

Let us consider stream consisting droplert under irradiation. Due to irradiation weakly-ionized plasma generates. The excitation and ionization of the vapor molecules takes placeand their clusters are formed. The droplet grows by absorbing both molecules and their clusters. Reducing the size of the droplet is due to thermal emission of its individual molecules, which depends on temperature and droplet radius.

Let *V* is volume per one drop. The total number of molecules in this volume is $n_0 V$. It consists of molecules of steam ( $n_g V$ ) and molecules included in clusters ( $mnV$ ) and in droplets ( $4\pi R^3 / 3v_0$ ) is constant ($n_0$).

Rate of change of the average density of the complexes ($n$) and the droplet radius ($R$) are described by the equations

$$\frac{dn}{dt} = Kn_g - n/\tau - 4\pi NRD_c n \tag{1}$$

$$\frac{dR}{dt} = \frac{v_0}{R}\left(D_g n_g + mD_c n - D_g n_g^{eR}\right) \tag{2}$$

Here $n_g^{eR} = n_g^e \exp\left(\frac{2\sigma v_0}{RkT}\right)$ and $n_g^e$ are equilibrium densities of molecules near droplet and far away from it. $N = 1/V$ is number of droplet per volume; $m$ is number of molecules in cluster. $K$ is part of molecules that ionizes (excites) per time. $\tau$ is life-time of cluster. $v_0$ is volume per molecule in droplet, $D_g$ and $D_c$ are diffusion coefficients of stream molecules and clusters.

A theoretical approach to evolution of complex density and the droplet radius is developed via formalism of Poincare. Our goal is to indentefy all possible quality different solutions of system (1) – (2) for different conditions and to build correspond phase portraits. We are going to indentefy their change for different irradiation conditions and substance properties.

Let us introduce new variables: $x = mD_c n / D_g n_g^e$, $y = R/r_0$, $t' = t/\tau$ and parameters $r_0 = (4\pi N/3)^{-1/3}$, $y_0 = 2\sigma v_0 / r_0 kT$, $x_0 = n_0 / n_g^e$, $\mu = D_g / D_c$, $\xi = 1 / v_0 n_g^e$, $\alpha = 3\tau D_c / r_0^2$, $\beta = mK\tau/\mu$, $\gamma = \tau D_g / \xi r_0^2 = \alpha\mu/3\xi$.

The changes of the droplet radius (y) and density of clusters (x) is completely determined by equations (1) - (2) and by the magnitudes of the drop and the density of clusters in the initial time. A set of initial conditions determines a set of solutions, which can be divided into classes. Every class includes qualitatively similar solutions. Solutions belonging to different classes are qualitatively different. A clear and adequate representation of such a partition into classes is given by the phase portrait.

The purpose of this paper is not to find explicit solutions, and an exhaustive description of all solution classes and the change of the partition into classes with the change of parameters. Change of parameters $\beta$, $x_0$ and $\mu$ is basically considered.

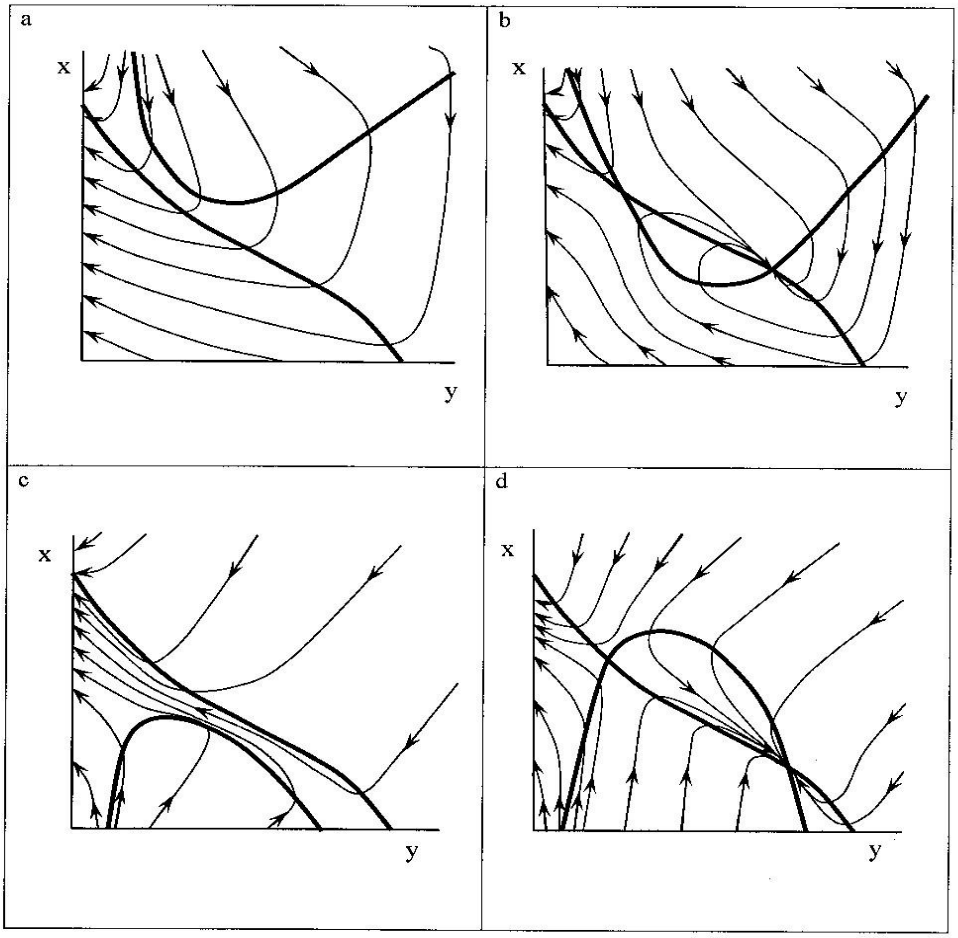


Figure 1 Phase portraits. a, b – for $\mu < 1$, c, d - for $\mu > 1$.

All possible phase portraits of systems of equations (1) – (2) are obtained and are shown on Fig. 1. The following information comes from their analysis.

When irradiation is absent, the clasters do not form, their density is equal zero. In this case change of droplet growth is determined by its initial size and the equation (2). When $x_0$ is less than the critical value, any stationary states are absent. So the droplet evaporets. When $x_0$ is more than the critical value, there are two stationary states. In this case if the droplet radus is less than the first lesser stationary radius (critical radius), the the droplet evaporates. If the droplets are more than critical one, they monotonically strive to the second stationary state.

Under irradiation change of droplet becomes more complicated. It depend on cluster generation rate and the ratio of the diffusion coefficients of clusters and molecules. When diffusion coefficient of the cluster is smaller than the one of free molecule, the stationary droplets exist for more wide region of parameters. At a low density of vapour, but sufficient for the existence of stationary droplet, the stationary droplet radius decreases, approaches to critical one, coincides with it and disappears when generation of exitation increases. At a larger density of vapour critical and a stationary radii converges to some limiting value that is the more, the more substance in the volume. The evaporation of droplet and its relaxation to the stationary value can be not monotone. At the beginning the drop grows and only then decreases and evaporates (see Figure 1(a) and Figure 1(b)). Such effect irradiation is explained by the fact that the generation of the nonmobile clusters decrease flux of substance to droplet. The accumulation of clusters decreases “effective” density of vapor and the droplet begins to evaporate.

If diffusion coefficient of the cluster is greater than the one of free molecule, irradiation expands the region of existence of stationary droplet. Evolution of droplet becomes more complicated. For some initial states it oscilates in time (see Figure 1(d)).