**Supplementary Information:**

## 1. Contributions to heterogeneous nucleation flux

The separation of the heterogeneous nucleation flux into “drift” and “diffusion in cluster size space” contributions is described in a number of earlier works in classical nucleation theory (Frenkel, 1946; Goodrich, 1964; Shizgal and Barrett, 1989; Ruckenstein and Nowakowski, 1990) and textbooks (Friedlander, 2000; Seinfeld and Pandis, 2006). A similar separation is also given in McGraw (McGraw, 2001). The separation of the flux following earlier works is briefly described below (Goodrich, 1964; Ruckenstein and Nowakowski, 1990). The net flux from clusters with $g$ condensed molecules to those containing $g$+1 condensed molecules is (Seinfeld and Pandis, 2006):

$$J_g = \beta_g f_g - \gamma_{g+1} f_{g+1} \qquad \text{(S1)}$$

Based on the continuum approximation, $J$ is approximated as a continuous function of $g$, and the gradient in $J_g$ with respect to $g$ is given by:

$$\frac{dJ_g}{dg} = J_g - J_{g-1} = \beta_g f_g - \gamma_{g+1} f_{g+1} - \beta_{g-1} f_{g-1} + \gamma_g f_g \qquad \text{(S2)}$$

Performing a second order Taylor expansion of the 2nd and third term of the right hand side of Eq. (S2) gives:

$$\begin{aligned} \gamma_{g+1} f_{g+1} &= \gamma_g f_g + \frac{d}{dg}\left(\gamma_g f_g\right) + \frac{1}{2}\frac{d^2}{dg^2}\left(\gamma_g f_g\right) \\ \beta_{g-1} f_{g-1} &= \beta_g f_g - \frac{d}{dg}\left(\beta_g f_g\right) + \frac{1}{2}\frac{d^2}{dg^2}\left(\beta_g f_g\right) \end{aligned} \qquad \text{(S3)}$$

Combining Eqs (S2) and (S3) gives:

$$\begin{aligned} \frac{dJ_g}{dg} &= \frac{d}{dg}\left(\beta_g f_g\right) - \frac{1}{2}\frac{d^2}{dg^2}\left(\beta_g f_g\right) - \frac{d}{dg}\left(\gamma_g f_g\right) - \frac{1}{2}\frac{d^2}{dg^2}\left(\gamma_g f_g\right) \\ &= \frac{d}{dg}\left[\left(\beta_g - \gamma_g\right) f_g\right] - \frac{1}{2}\frac{d^2}{dg^2}\left[\left(\beta_g + \gamma_g\right) f_g\right] \end{aligned} \qquad \text{(S4)}$$

Integrating the above equation (S4) gives the desired separation of the flux into contributions from the drift in the force field and diffusion in cluster size space:

$$\begin{aligned} J_g &= f_g\left(\beta_g-\gamma_g\right)-\frac{1}{2}\frac{d}{dg}\left[\left(\beta_g+\gamma_g\right)f_g\right] \\ &= \overbrace{f_g\left(\beta_g-\gamma_g\right)}^{\text{DRIFT}}\ \overbrace{-\frac{1}{2}\nabla_g\left[\left(\beta_g+\gamma_g\right)f_g\right]}^{\text{DIFFUSION IN CLUSTER SIZE SPACE}} \end{aligned} \qquad \text{(S5)}$$

## 2. Comparison of $GR_{drift}$ and $GR_{cond}$

The size-dependent per-particle condensation rate $\beta_g$ is given by (Seinfeld and Pandis, 2006):

$$\beta_g=\frac{\pi}{4}\left(D_p+D_m\right)^2\bar{c}_\mu C_\infty \qquad \text{(S6)}$$

The size-dependent per-particle evaporation rate is related to the condensation rate by (Seinfeld and Pandis, 2006):

$$\gamma_g=\frac{\beta_{g-1}C_S}{C_\infty}\exp\left[\frac{\sigma\left(a_g-a_{g-1}\right)}{kT}\right] \qquad \text{(S7)}$$

where $a_g$ is the surface area of the growing cluster consisting of the initial cluster (seed) and $g$ monomers of condensate. Letting $D_s$ denote the size of the initial cluster, the size of the growing cluster is:

$$D_p=\left(D_s^3+gD_m^3\right)^{1/3}$$

Given its small volume, addition of a monomer leads to a small increase in cluster diameter. Employing the continuum approximation at large $g$, we have:

$$
\begin{aligned}
a_g - a_{g-1} = \nabla_g a = \nabla_g \left[ \pi \left( D_s^3 + g D_m^3 \right)^{2/3} \right] \\
&= \frac{2}{3} \pi \left( D_s^3 + g D_m^3 \right)^{-1/3} D_m^3 \\
&= 4 \frac{1}{6} \pi D_m^3 \left( D_s^3 + g D_m^3 \right)^{-1/3} \\
&= \frac{4v}{D_p}
\end{aligned}
\tag{S8}
$$

Similarly, the gradient of the size of the growing cluster is given by:

$$
\nabla_g D_p = \nabla_g \left[ \left( D_s^3 + g D_m^3 \right)^{1/3} \right] = \frac{1}{3} \left( D_s^3 + g D_m^3 \right)^{-2/3} D_m^3 = \frac{\frac{\pi}{6} D_m^3}{\frac{\pi}{2} D_p^2} = \frac{v}{\frac{\pi}{2} D_p^2}
\tag{S9}
$$

Inserting equation (S8) into equation (S7), $\gamma_g$ can be written as:

$$
\begin{aligned}
\gamma_g = \frac{\beta_{g-1} C_S}{C_\infty} \exp\left( \frac{\sigma \nabla_g a}{kT} \right) \approx \frac{\beta_g C_S}{C_\infty} \exp\left( \frac{\sigma \nabla_g a}{kT} \right) \\
= \frac{\beta_g C_S}{C_\infty} \exp\left[ \frac{4 \sigma v}{kT D_p} \right]
\end{aligned}
\tag{S10}
$$

Combining equations (S6), (S9), and (S10), we can show that the traditional condensation growth rate is essentially the contribution of drift term to the total growth rate:

$$
GR_{drift} = \left( \nabla_g D_p \right) \left( \beta_g - \gamma_g \right) = \frac{1}{2 D_p^2} \left( D_p + D_1 \right)^2 \bar{c}_\mu v \left[ C_\infty - C_S \exp\left( \frac{4 \sigma v}{kT D_p} \right) \right] = GR_{cond}
\tag{S11}
$$

**Supplementary References:**


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