

### 020418 Quiz 3 Nanopowders

- 1) For particles undergoing Ostwald ripening
  - how would you plot** particle size versus time to determine if the process was reaction limited or diffusion limited?
  - Could a** final particle size distribution curve for the two conditions distinguish between the two mechanisms? (Give a qualitative answer (no equations))  
For surface deposition of monomers to a cluster through a diffusion layer, we obtained  $dr/dt \sim 1/r$  for diffusion limited growth and  $dr/dt \sim K$  (i.e. not a function of  $r$ ) for reaction limited growth.
  - What is** the time dependence of particle size for these two conditions,
  - can you** distinguish between monomer cluster growth and Ostwald ripening?
  - and **how would** you plot particle size versus time to distinguish these two conditions?
  
- 2)
  - Give** the functional form for a log-normal distribution.  
If you were given the particle size distribution,  $n_d(d_p)$ ,
  - how would** you calculate the mean size,  $\langle d_p \rangle$ ,
  - mean surface** area per particle,  $\langle A_p \rangle$ ,
  - and the mean** particle volume,  $\langle V_p \rangle$ ?
  - Generally**, which is larger  $\{6\langle V_p \rangle / \}^{1/3}$  or  $\langle d_p \rangle$ ? Why?
  
- 3) -**Compare** the Kelvin equation and the Gibbs-Thompson equation by writing both and explaining the differences. (Explain the relationship between the pressure of an ideal gas and the molar concentration of atoms.)

### Answers: 020418 Quiz 3 Nanopowders

- 1) For reaction limited Ostwald ripening,  $d_p \sim t^{1/2}$  so a plot of  $d_p^2$  versus time would be linear.  
 For reaction limited Ostwald ripening  $d_p \sim t^{1/3}$  so a plot of  $d_p^3$  versus time would be linear.  
 You could also make a log log plot of  $d_p$  versus  $t$  and look for power law slopes of 2 and 3.

The final particle size distribution is much broader for reaction limited growth so it could potentially be used to distinguish between the two. (functional forms for the particle size distribution are available from LSW theory.)

For monomer-cluster surface deposition with diffusion limited growth  $dr/dt \sim 1/r$  so  $r^2 \sim t$  and a plot of  $r^2$  versus  $t$  should be linear. This is identical to reaction limited Ostwald ripening.

For reaction limited monomer-cluster growth  $r \sim t$ , so a plot of  $r$  versus  $t$  is linear.

Reaction limited monomer-cluster growth and diffusion limited Ostwald ripening have unique time dependencies so can be distinguished.

- 2)

$$n_d(d_p) = \frac{N}{(2 \ln g)^2 d_p} \exp \frac{-(\ln d_p - \langle \ln d_{pg} \rangle)^2}{2(\ln g)^2}$$

The moments of the distribution are defined by,

$$M_n(r, t) = \int_0^\infty n_d d_p^n d(d_p)$$

$$\langle d_p \rangle = M_1/M_0$$

For spherical particles

$$\langle A_p \rangle = \frac{M_2}{M_0}$$

and

$$\langle V_p \rangle = \frac{M_3}{6M_0}$$

The higher order moments give greater weight to the larger sizes so generally,  $\{6\langle V_p \rangle\}^{1/3} > \langle d_p \rangle$ .

- 3)

$$\ln \frac{p}{p_s} = \frac{2 \bar{v}_B}{rRT} \quad \text{Kelvin Equation}$$

$$\ln \frac{x}{x_s} = \frac{2v_1}{rkT} \quad \text{Gibbs-Thompson Equation}$$

So the two equations are identical except that pressure takes the place of molar concentration. For an ideal gas the molar concentration,  $x = n/V = p/RT$ , so the Kelvin equation is the Gibbs-Thompson for an ideal gas.